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Ground Cloud Dispersion Measurements During The Titan IV Mission #K2 (3 July 1996) at Cape Canaveral Air Station

Volume 1—Test Overview and Data Summary

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Launch plume imagery and ground HCl measurements were accomplished during the launch of Titan IV Mission #K2 at Cape Canaveral Air Station on 3 July 1996. These data will be used to improve the accuracy of the Rocket Exhaust Effluent Diffusion Model. The imagery from three sites (integrated IR and visible imagers at each) showed a cloud stabilization height of 1871 m (72% higher than predicted), reached in 10–14 min (4% to 46% longer than predicted). The cloud trajectory was east-northeasterly, similar to prediction, and the 6.2 m/s speed was 44% faster than predicted. Aircraft HCl measurements were not taken for this launch. Ground dosimeters around the launch pad measured dosages as high as 378 ppm min.

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Preface

The Air Force Space and Missile Systems Center's Launch Programs Office (SMC/CL) is sponsoring the Atmospheric Dispersion Model Validation Program (MVP). This program is collecting launch cloud dispersion data that will be used to determine the accuracy of atmospheric dispersion models, such as REEDM, in predicting toxic hazard corridors at the launch ranges. This report presents launch cloud dispersion and meteorological measurements performed during the #K2 Titan IV launch at Cape Canaveral Air Station on 2 July 1996.

An MVP Integrated Product Team (IPT) led by Capt. Brian Laine (SMC/CLNM) is directing the MVP effort. Dr. Bart Lundblad of The Aerospace Corporation's Environmental Systems Directorate (ESD) is the MVP technical manager. This report was prepared by Mr. Norm Keegan (ESD) and Dr. Lundblad from materials contributed by personnel participating in the #K2 launch cloud dispersion measurements.

Visible and infrared imagery measurements were made of the launch cloud by Dr. Robert Abernathy, Ms. Karen Foster, Mr. Gary Harper, Mr. Brian Kasper, Mr. Bob Klingberg, and Mr. Tom Knudtson of The Aerospace Corporation's Environmental Monitoring and Technology Department (EMTD). Field assistance was provided by Dr. Bart Lundblad. Mr. Doug Schulthess of Aerospace's Eastern Range Directorate coordinated site selection and logistical support with Range organizations. Ms. Foster digitized the imagery data for analysis by Dr. Abernathy. The description of the cloud imagery results was prepared by Dr. Abernathy.

Aerial HCl measurements of the ground cloud were not conducted during the #K2 launch because the launch was at night. Ground HCl measurements were limited to the launch pad area because the cloud was predicted to disperse over the ocean.

The REEDM illustrations in Appendix A were provided by Dr. Abernathy. The meteorological data displayed in Appendix B were provided by Mr. Randy Evans of the NASA Applied Meteorology Unit and ENSCO, Inc.

The #K2 mission was the eighth Titan IV launch for which usable launch cloud dispersion data were collected by MVP. The previous missions were #K7, #K23, #K19, #K21, #K15, #K16, and #K22.

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Executive Summary

This report presents plume imagery and ground-based hydrogen chloride (HCl) sampling data documenting the development and dispersion of the Titan IV #K2 launch ground cloud at Cape Canaveral Air Station (CCAS). The launch took place on 3 July 1996 at 0030 Zulu time. The report also presents pertinent meteorological data taken from towers and rawinsonde balloons.

The imaging team successfully tracked the trajectory and time evolution of the vehicle's exhaust ground cloud for 34 min following launch using two infrared and one visible light camera systems. HCl dosimeters were deployed around the launch pad to determine ground-level HCl dosages.

Meteorological data were collected to improve understanding of cloud dispersion and to use as input during model simulations and evaluations. Rawinsonde balloon data from shortly before launch and meteorological tower data from shortly before and after launch were collected and archived. These data and similar data on other Titan IV launches (past and future) will be used to determine the accuracy of atmospheric dispersion models such as the Rocket Exhaust Effluent Diffusion Model (REEDM) in predicting toxic hazard corridors (THCs) at the USAF Eastern and Western Ranges. These THCs assess the risk of exposing the public to HCl exhaust from solid rocket motors or hypergolic propellant vapors accidentally released during launch operations.

Reduction of imagery data from the first 26 min following launch yielded the stabilization height, rise time, ground track, and speed of the ground cloud. Comparison to REEDM 7.07 predictions show that the imagery-derived stabilization height (1871 m) is 72% higher than predicted by REEDM (1087 m), and that the imagery-derived time to stabilization (10–14 min) is 4–46% longer than the REEDM-predicted stabilization time (9.6 min). The imagery-derived ground track of the cloud (248°) is within the track predicted by REEDM (235°–253°). The imagery-derived velocity of the cloud (6.2 m/s) is 22% faster than the rawinsonde wind measurement (5.1 m/s) and 44% faster than the velocity predicted by REEDM (4.3 m/s).

Ten HCl dosimeters were deployed inside the perimeter fence at LC-41. All seven of the recovered dosimeters showed measurable doses of HCl exposure (0.04–378 ppm-min). Mobile sampling teams equipped with Interscan HCl detectors did not detect any HCl in nearby onshore locations because the cloud was blown directly out to the ocean.

1. Introduction

Launch vehicles that employ solid propellant rocket motors release exhaust ground clouds containing large quantities of hydrogen chloride (HCl) into the launch areas at Cape Canaveral Air Station (CCAS) and Vandenberg Air Force Base (VAFB). Large quantities of hazardous liquid fuels and oxidizers could also be released as a result of propellant transfer accidents or launch vehicle failures. The Air Force uses atmospheric dispersion models to predict the downwind diffusion and concentration of toxic launch clouds. There exists a strong need to collect launch cloud data that can be used to test and validate the performance of these dispersion models.

The Air Force range safety organizations at Patrick Air Force Base (45 SW/SE) and VAFB (30 SW/SE) are responsible for assuring that launches occur only when meteorological conditions will not expose nearby public areas to hazardous levels of launch exhausts and propellant vapors. Predictions of toxic hazard corridors that extend into public areas can lead to costly launch delays. The present use of non-validated models requires the use of conservative launch criteria. The development and validation of accurate atmospheric dispersion models is expected to increase launch opportunities and significantly reduce launch costs. The Space and Missile Systems Center's Launch Programs Office (SMC/CL) established the Atmospheric Dispersion Model Validation Program (MVP) to collect launch cloud data and to use the data to test and validate current and future atmospheric dispersion models at the ranges.

The MVP effort involves the collection of data during Titan IV launches at CCAS and VAFB to characterize HCl launch cloud rise, growth, and stabilization, as well as launch cloud transport and diffusion. These data, along with data collected during tracer gas releases, will be used to determine the capability of the Rocket Exhaust Effluent Diffusion Model (REEDM) for predicting toxic hazard corridors at the ranges. REEDM is used at CCAS and VAFB to predict the locations of toxic hazard corridors in support of launch operations. It is applied to large heated sources of toxic air emissions such as nominal launches, catastrophic failure fireballs, and inadvertent ignitions of solid rocket motors. It uses launch vehicle and meteorological data to generate ground-level concentration isopleths of HCl, hydrazine fuels, nitrogen dioxide, and other toxic launch emissions. Launch holds may occur when REEDM toxic concentration predictions exceed adopted exposure standards. REEDM is a unique and complex model based on relatively simple modeling physics. It has a long development history with the Air Force and NASA, but has never been fully validated. Validation of REEDM has been identified as a range safety priority.

The MVP has been organized and is being directed by the MVP Integrated Product Team (IPT). SMC/CL is serving as the IPT leader, while The Aerospace Corporation's Environmental Systems Directorate serves as the IPT technical manager. The IPT consists of personnel with expertise in atmospheric dispersion modeling, meteorology, and atmospheric dispersion field studies. MVP participants include personnel from SMC, 30 SW, 45 SW, Armstrong Laboratory, The Aerospace Corporation, NASA, NOAA, and contractors. Key functions include program planning, field data collection, data review and compilation, range coordination, and model validation.

This report presents the results of measurements performed at CCAS during the Titan IV #K2 launch on 3 July 1996. Visible and infrared measurements were made on the ground cloud to

monitor its growth, stabilization, and trajectory. Ground-level HCl doses were measured at selected locations at the launch site. The imagery results are presented in Section 2, and Section 3 describes the ground-level HCl measurements at the launch pad. REEDM predictions of ground cloud stabilization heights and surface concentrations are presented in Appendix A. Measurements of meteorological data are tabulated in Appendix B. The imagery and HCl concentration results presented in this, as well as other MVP reports, will allow the accuracy of REEDM and other launch range atmospheric dispersion models to be determined over the range of possible meteorological conditions.

2. Imagery of the Titan IV #K2 Ground Cloud

[The material in this section was contributed by R. N. Abernathy, K. L. Foster, and B. P. Kasper of the Environmental Monitoring and Technology Department of The Aerospace Corporation's Space and Environment Technology Center.]

2.1 Background

On 02 July 1996, the Titan IV #K2 mission was successfully launched from Space Launch Complex 40 (SLC-40) at Cape Canaveral Air Station (CCAS) at 2030 EDT (0030 GMT). This section describes the quantitative exhaust cloud imagery data collected by each of three imagery sites during the 34 min immediately following the launch from SLC-40. This section also describes the data acquisition hardware and analysis software. The two-dimensional cloud images obtained by the various imagery sites were combined in a pair-wise fashion to produce stereoscopic 3-D information. This analysis yielded the cloud's rise time, stabilization height, speed, bearing, and cross-wind growth rate during the 26 min immediately following launch.

The quantitative imagery-derived ground cloud data are reported here in several graphical formats to facilitate comparison with REEDM predictions (Appendix A) and rawinsonde sounding data (Appendix B). For clarity, this section includes some data from the appendices. It is apparent from review of this section, that these data are useful for validating current and future dispersion models.

The purpose of this report was to document the quality and quantity of the #K2 exhaust cloud imagery data available for validating dispersion models. However, it is difficult to extract the data for a single instant in time from summary plots that contain many minutes of ground cloud data. Therefore, in order to facilitate the comparison of these data to individual dispersion model runs, a subsequent report will provide a detailed review of the imagery. This subsequent detailed analyses will provide the data in a format that will allow direct comparison to model runs for specific times, altitudes, and distances from the release site.

The imagery-derived #K2 exhaust cloud imagery data are also available as comma-separated-variable files providing time and position for various ground cloud features. The raw visible imagery data are archived on VCR tapes. The raw infrared imagery are archived on DAT. The selected visible and infrared images analyzed for this report are also archived on magneto-optical disks as digital image files.

2.2 Introduction

This section summarizes the results of quantitative visible and infrared imagery of the exhaust cloud from the Titan IV #K2 launch from SLC-40 at CCAS on 02 July 1996 at 2030 EDT (0030 GMT). Personnel from The Aerospace Corporation's Environmental Monitoring and Technology Department (EMTD) supported this launch with the deployment of three complete platforms of the Titan IV-dedicated Visible and Infrared Imaging System (VIRIS). For the #K2 evening launch, the imagery from three sites permitted the post-launch quantitative analysis of the ground cloud's movement and growth as a function of time. The imagery sites chosen for the #K2

launch were UCS-7 (north-northwest of the SLC-40), SLC-34 access road (south-southeast of the SLC-40), and the Static Test Viewing Site (west southwest of the SLC-40). A hardware failure at the SLC-34 site prevented collection of infrared imagery, so the visible imagery was used from that site. Infrared imagery was used from the other two sites.

Quantitative analysis of the visible and infrared imagery from the sites for the first 26 min after launch documented the cloud's rise time, stabilization height, bearing, speed, and cross-wind growth without recourse to other data. The "ground cloud" is defined as the lower and more concentrated portion of the rocket's exhaust cloud that can diffuse to the ground. The "launch column" is defined as the trail of the rapidly moving rocket that extends above the more spherical "ground cloud."

The T-0.8h rawinsonde pre-launch meteorology data are documented in Appendix B and referenced in this section. Those rawinsonde wind data were used to run the "normal launch" REEDM predictions. The complete T-0.8h REEDM predictions are documented in Appendix A and referenced in this section.

2.3 Field Deployment

2.3.1 Planning

The Aerospace Corporation's participants are listed in various teams below (members of the imaging teams for #K2 are indicated with asterisks):

Technology Operations
Space and Environment Technology Center
Environmental Monitoring and Technology Department

R. N. Abernathy*	(SLC-34 Access Road)
K. L. Foster* and J. T. Knudtson*	(Static Test Viewing Area)
B. P. Kasper* and G. N. Harper*	(UCS-07 -- VIRIS)
R. A. Klingberg* and E. J. Beiting, III*	(UCS-07 -- SPCI)

Space Launch Operations
Systems Engineering Directorate
Environmental Systems

N. F. Dowling, Systems Director	
H. L. Lundblad*	(SLC-34 Access Road)

Eastern Range
Systems Engineering Directorate
D. R. Schulthess

2.3.2 Equipment

The equipment at each site included all the hardware and software necessary to record and document the launch, to communicate between sites, and to supply backup power in case of an outage at the fixed-power distribution points. The VIRIS consists of an array of three full and one backup (excluding the IR imager) cloud tracking systems and was designed and fabricated at the request of Space Launch Operations, Systems Engineering Directorate, at The Aerospace Corporation. Each full tracking system consists of coaligned visible and infrared (IR = 8–12 μm) imagers, mounted on an azimuth- and elevation-encoding tripod, with an associated data acquisi-

tion and display console. The combination of visible and IR imagers permits cloud tracking in both daylight and darkness. The unique capabilities built into the VCR hardware include digital insertion of imager azimuth (AZ), elevation (EL), time, and GPS location. The system electronics are integrated in a single package, which has been ruggedized for field use. Pre-wiring of this package makes deployment of these imager systems straightforward, usually requiring less than 45 min for instrumentation at a site to become fully operational.

For the Titan IV #K2 mission, the operators at each site set the FOV of the visible imager to its maximum for its 10 to 110 mm electronic zoom lens and used the widest lens for the infrared imagers (see Table 1). The operator at the SLC-34 site (i.e., with the failed Agema) continuously adjusted the iris setting to maximize contrast for detection of the edge of the ground cloud in the visible imagery. All operators rotated the tripod head to keep the ground cloud within the FOV as it moved from the launch pad.

All three imaging systems deployed for the Titan IV #K2 mission were capable of total autonomy. Each VIRIS has an on-board differential-ready GPS receiver that can be used to document each imager's position with moderate spatial resolution. Typically, 35 m is the precision in the horizontal plane, and 100 m is the precision in the vertical plane. A separate, portable 2-m-resolution GPS receiver was used to survey the imagery sites used for the #K2 mission. Gasoline-powered AC generators (Honda Ex1000) are insurance against loss of fixed power. The Stirling cooler option for the AGEMA 900 series IR imager was chosen so that liquid nitrogen would not be required at the sites. Each unit is transportable in a standard utility wagon (e.g., Ford Explorer).

The AZ/EL angle encoder for all imager systems was calibrated using reference objects (e.g., SLC-40) within the field of view of the imager. When reference objects are not part of the geodetic survey database, the GPS location uncertainty is the dominant term in the positional accuracy. Imager pixelation and operator error in edge detection contribute as well to the error in defining the cloud boundary. The 0.07° step-size in the tripod angle encoders is a third source of error. The analysis accuracy is determined either by the availability of optimal references for AZ/EL calibration or by the step size for the tripod angle encoder. Typically the VIRIS system provides 0.1° accuracy in both elevation and azimuth.

Table 1. Field of View (FOV) for Imagery Sites during #K2 Mission

Imagery Site	Imager Type (Visible or IR)	FOV(horizontal) (deg)	FOV(vertical) (deg)
UCS-07	AGEMA Infrared	41.45	21.00
Static Test Viewing	AGEMA Infrared	41.45	20.70
SLC-34	Visible CCD	31.62	24.96

2.4 Processing of Imagery Data

The processing of the imagery data requires several transformations that are performed upon return to The Aerospace Corporation:

1. Digitizing frames of the visible imagery
2. Measuring the pixel locations of the reference sites within each image (i.e., FOV and angular calibration)
3. Measuring the pixel locations of cloud features in digitized images
4. Converting pixel locations to azimuth and elevation readings
5. Calculating cloud characteristics (i.e., position in Cartesian coordinates relative to the launch pad)

The processing requires the use of specialized hardware and software. Visible images of the cloud are digitized at precise times, beginning with time intervals of 15 s, then 30 s, then 1 min as the cloud evolves. The AGEMA 900 imagers produce digital images every 15 s in the field for the infrared imagers. A set of digitized images is selected for specific times following the launch and from each of the available imagery sites. Time, AZ, and EL are tabulated for each set. A setup file containing all relevant information necessary to compute the cloud geometry is created for each of these sets. The Aerospace program **PLMTRACK** is run to digitize the x, y, and z coordinates of cloud features. The x and y coordinates are reported relative to the launch pad while the z coordinate is reported as height above mean sea level (MSL). We converted the height above MSL to height above ground level (AGL) by subtracting the 7 m MSL for the height of SLC-40. This allows direct comparison to REEDM's output.

PLMTRACK is a software program developed in the Environmental Monitoring and Technology Department (EMTD) of The Aerospace Corporation by Brian P. Kasper. It is designed to analyze pairs of cloud images synchronized in time. When using the **PLMTRACK Line Method**, the operator selects the location of a particular cloud feature in the images from the two imager sites by moving a screen pointer to the desired feature in each image and clicking a mouse button. **PLMTRACK** then calculates the point of nearest approach to the two rays defined by the selected points. The three-dimensional location of this feature is then written to a data file.

Another implementation of **PLMTRACK** is illustrated in Figure 1. When using the **PLMTRACK Box Method**, the operator draws a rectangle about a cloud feature in the images from the two imager sites by moving a screen pointer to the extreme corners of the rectangles and clicking a mouse button. **PLMTRACK** then calculates the closest approach for various rays as illustrated in Figure 1 and described below. The top of the cloud is defined by rays determining T1 and T2 (i.e., T1 $\times$ T2); the bottom is

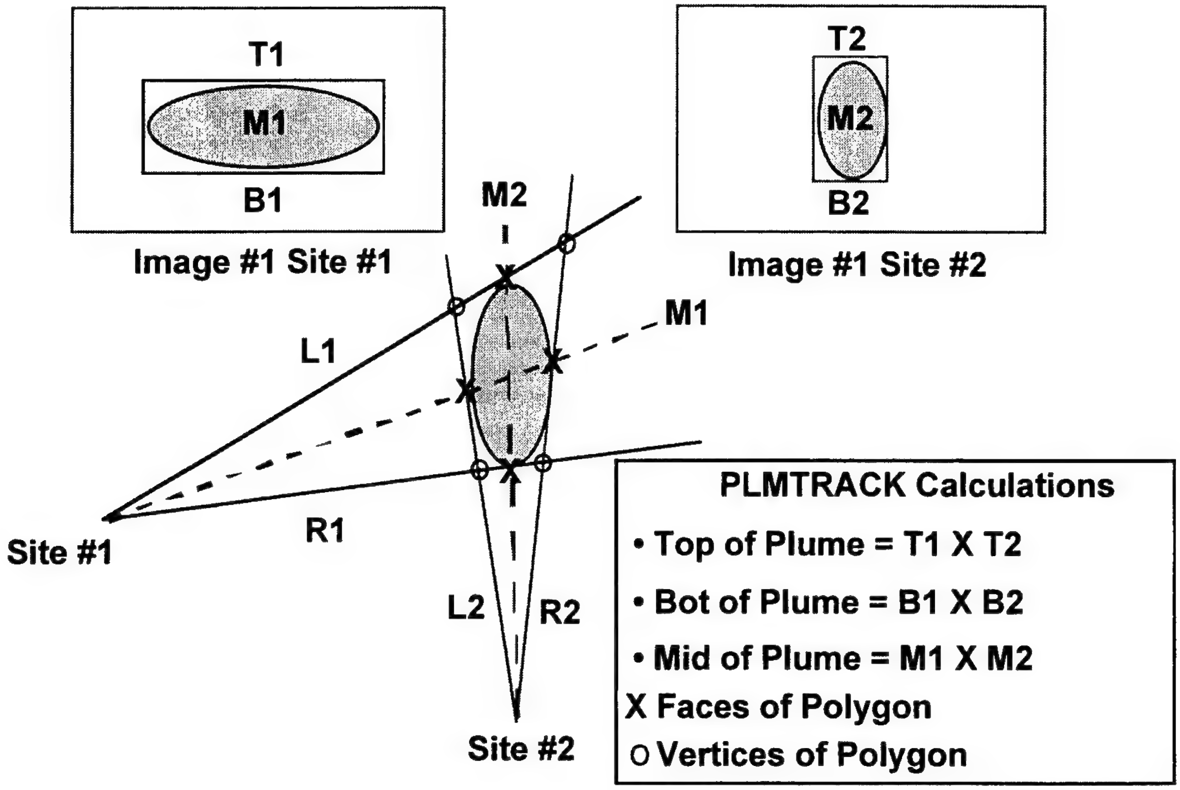


Figure 1. Implementation of the "box" method with two imagers.

determined by rays defining B1 and B2 (i.e., B1 × B2), and the middle is defined by the geometric mean of top and bottom (i.e., M1 × M2). To define the "faces" of the "box," the points of closest approach for ray M1 with L2 and R2 (the left and right tangents to the cloud from Imager 2) are defined (i.e., M1 × L2 and M1 × R2). A similar procedure is used to define the points of closest approach for M2 with L1 and R1, yielding M2 x R1 and M2 x L1. In addition to the centers of the faces of the "box," the intersects of the left and right rays document the four vertices for the XY polygon. Thus, eleven points are defined for the six-faced "box" surrounding the cloud (a point in the center of each of the six faces, four vertices for the XY polygon, plus a middle point for the "box"). These eleven sets of x, y, and z coordinates are written to a file.

When three imagers are viewing the cloud simultaneously, a six-sided polygon method (documented in Figure 2) has been employed as a way to document the maximum extent of the cloud (i.e., a ground-plane projection) for each set of images. With three imagers, there is a triply redundant determination of the top, middle, and bottom of the cloud by **PLMTRACK**. The horizontal extent of the cloud is determined by defining the rays from each imager that are tangential to the widest part of the cloud as seen from that site. Projection of these extreme rays for each imager on the x-y ground plane forms a polygon that bounds all material in the cloud at all altitudes, as shown in Figure 2. Thus, when an aircraft is flown against the ground cloud (i.e., #K15, #K16, #K22, and #K23 missions), one expects to see aircraft HCl sampling "hits" fall within this polygon, regardless of the sampling altitude. When the polygon area is combined with the mean

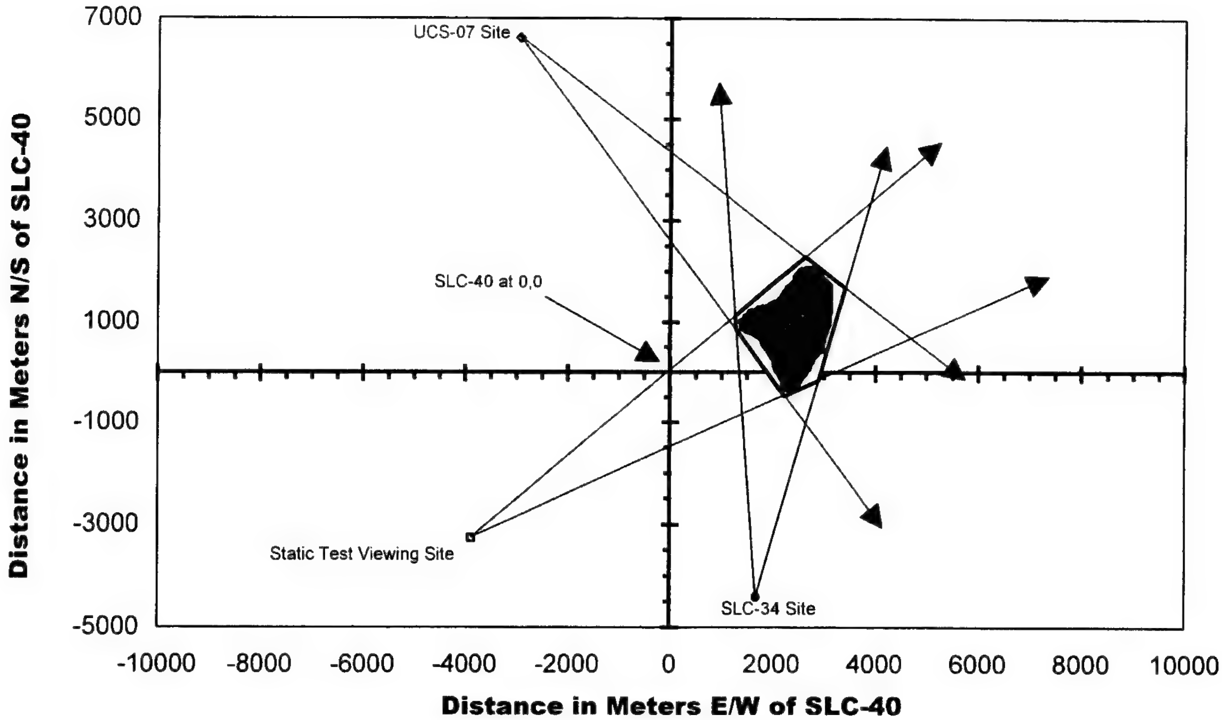


Figure 2. Implementation of the polygon method for two imagers. The imager positions and rays are actual #K2 data for T+05:00 (mm:ss) after launch. The cloud's shape was synthesized for heuristic purposes to illustrate that the shaded polygon can overestimate the clouds extent.

cloud height (i.e., the difference between the top and the bottom of the cloud), one can obtain an upper bound for cloud volume. As illustrated in Figure 2 (a ground projection of the cloud's extent), the shaded area within the polygon typically overestimates the extent of the cloud (i.e., the smaller shape drawn within the polygon).

The utility of the polygon method has been documented in a previous report[1] for the #K23 mission. In that report, the polygons from imagery were correlated with aircraft's HCl measurements of cloud dimensions and average HCl concentrations for the Titan IV #K23 launch cloud. After correcting for Geomet time response, the #K23 dataset established that HCl concentrations detectable by an aircraft-based Geomet total HCl detector were mostly contained by the six-sided polygon areas for the first 20 min after launch. The #K23 data established that the imagery-derived position of the visible cloud correlates with the measurable HCl concentrations. A similar treatment is possible with the #K2 imagery (without aircraft data) and allows a mapping of the growth and position of the cloud over time.

2.5 Results and Discussion

2.5.1 Correlation of Ground Cloud Bearing with Wind Direction

Figure 3 presents the imagery-derived and the T-0.8h REEDM-predicted ground cloud trajectories as arrows drawn on a map. Figure 3 also documents the rawinsonde wind directions at the imagery-derived top, middle, and bottom of the stabilized ground cloud. Lastly, Figure 3

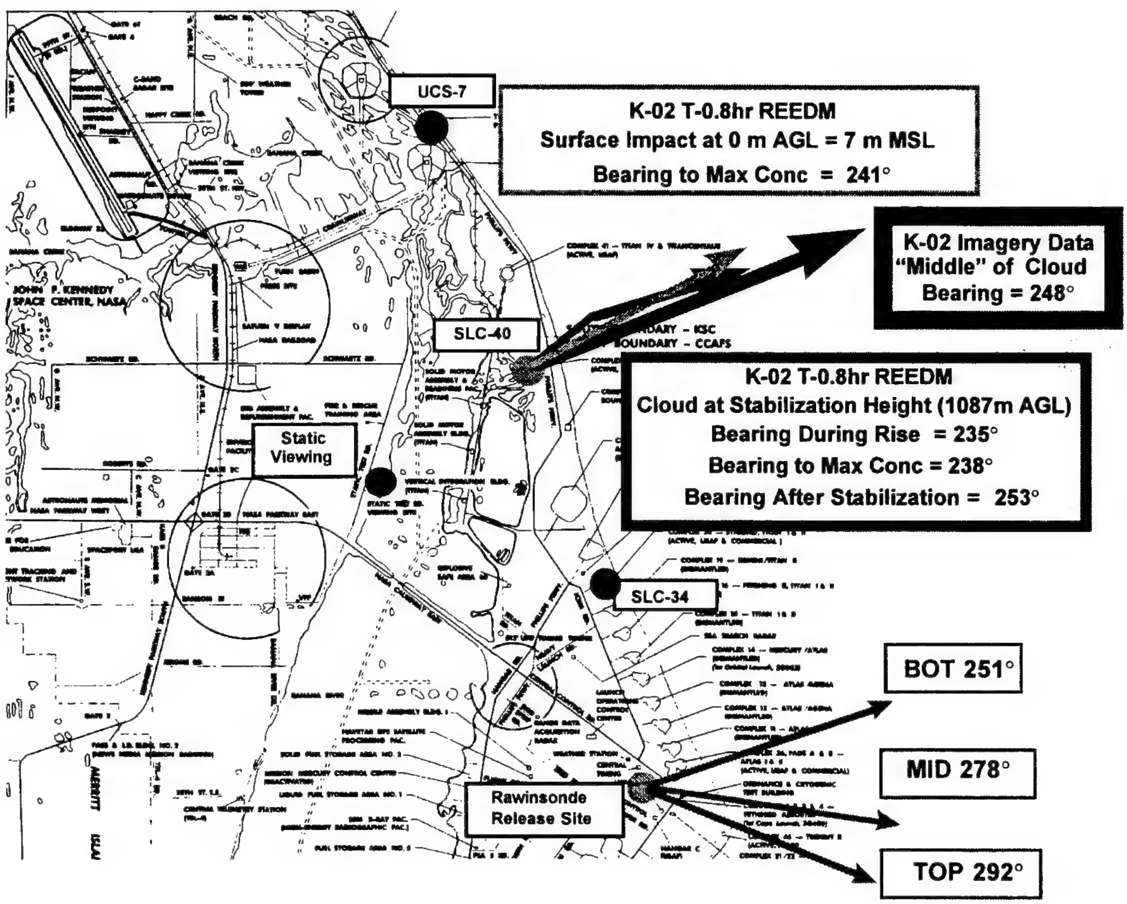


Figure 3. Map documenting the imagery sites, the rawinsonde release site, the #K2 ground cloud's bearing (derived from visible and infrared imagery), the T-0.8h REEDM prediction for the ground cloud's bearings, and the 2345 GMT (T-0.8h) rawinsonde wind directions at the measured cloud stabilization heights.

documents the locations of the rawinsonde release site and of the three imager sites (UCS-7, Static Test Viewing Site, and SLC-34) used by The Aerospace Corporation while imaging the #K2 cloud. All directions are reported in rawinsonde convention (defined fully in Subsection 2.5.4). Briefly, the arrows indicate the direction that the cloud would move for a wind coming from the indicated angle (clockwise from north).

As illustrated in Figure 3, the quantitative imagery documented a 248° bearing (i.e., wind from southwest pushing the cloud to the northeast). REEDM predicts a bearing of 235° for the rising cloud. At the predicted stabilization height (i.e., 1087 m AGL), the cloud's predicted bearings were 238° to the maximum cloud concentration and 253° at later times (based upon average wind in the mixing layer). At ground level, the cloud's predicted bearing was 241° to the maximum ground-level concentration. Figure 3 also presents the rawinsonde-derived wind directions (251°, 278°, and 292°) associated with the rawinsonde sounding heights (1324, 1897, and 2652 m AGL) nearest the bottom, middle, and top of the stabilized ground cloud, respectively. These wind directions are from the T-0.8h rawinsonde data and at the indicated sounding heights, which are closest to the imagery-derived heights of 1370, 1871, and 2635 m AGL for the bottom, middle, and top of the ground cloud, respectively. Since SLC-40 is at 7 m MSL, you must add 7 m to height AGL to convert it to height MSL.

Figures 4 through 7 are selected visible and infrared images of the Titan IV #K2 launch cloud from the indicated sites at the specified times after launch. Each figure contains two images (early and later times) from each site. It is immediately obvious that the cloud is not spherically symmetrical in any of these images, and that the geometry of the cloud changes rapidly in the first few minutes after launch.

Figure 4 documents the cloud at the earliest times (1 and 2 min after launch) while the SLC-40 MST is still in the FOV in the visible imagery from SLC-34 site. It is apparent that the cloud moves toward the ocean (i.e., the right from SLC-34's perspective). In the upper image (i.e., 1 mi after launch), the ground cloud is defined as the wider portion of the exhaust cloud. In the lower image (i.e., by 2 min after launch), the top of the ground cloud is the same width as the lower portion of the launch column. The analyst uses eddy structure to track the rising ground cloud based upon review of all of the imagery.

Figure 5 documents more visible imagery from SLC-34 site for 4 and 6 min after launch. In these images, the ground cloud has a denser upper portion and a quickly dissipating lower portion. The ground cloud almost fills the vertical FOV from this site.

Figures 6 and 7 document imagery for two sites, UCS-07 and Static Test Viewing Sites, respectively. The UCS-07 imagery at 1 min (upper image in Figure 6) is practically a mirror image for the SLC-34 site at 1 min (upper image in Figure 4). As was the case for early imagery from SLC-34, ground structures and the tree line are evident in the early imagery (upper images of Figures 6 and 7) from UCS-07 and Static Test Viewing Site, respectively. The infrared imagery provided excellent contrast for defining the top of the ground cloud as documented by the later imagery (lower image in Figure 6) from UCS-07 site.

The imagery data were subjected to an iterative analysis to ensure that only cloud features contributing to the stabilized ground cloud (as documented by the entire 26 min of imagery) were included in the **PLMTRACK** "boxes." In spite of the late hour (i.e., the sunset) and the hazy background, both the visible and the infrared imagery provided excellent contrast for detecting the edges of the cloud at all altitudes.

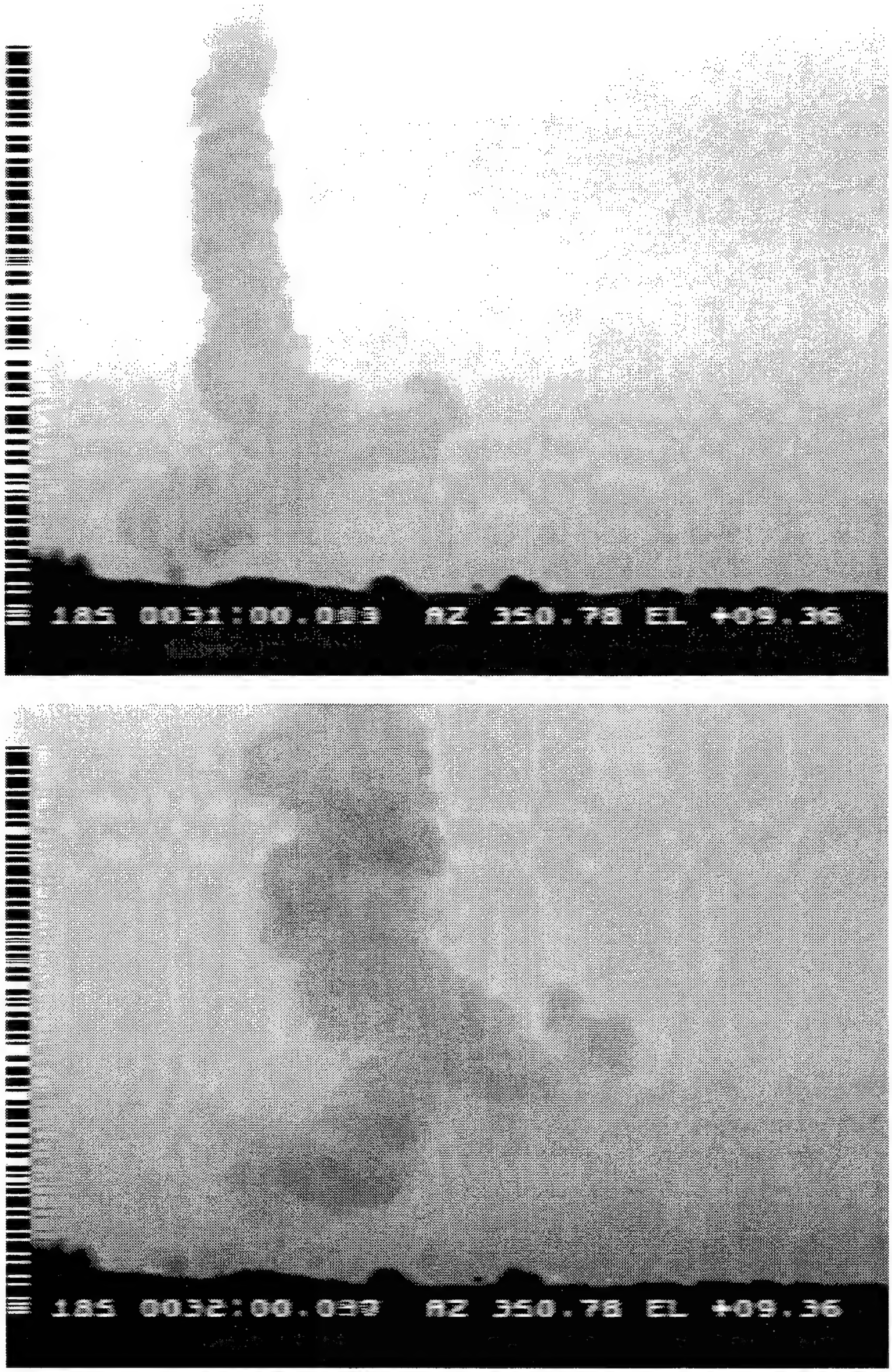


Figure 4. Visible imagery from SLC-34 site with rising ground cloud and with SLC-40 in the FOV: (a) Upper image at T+01:00 (mm:ss) with bottom of the ground cloud still at the height of the MST; (b) lower image at T+02:00 (mm:ss) with ground cloud moving to the right (i.e., east) and rising.

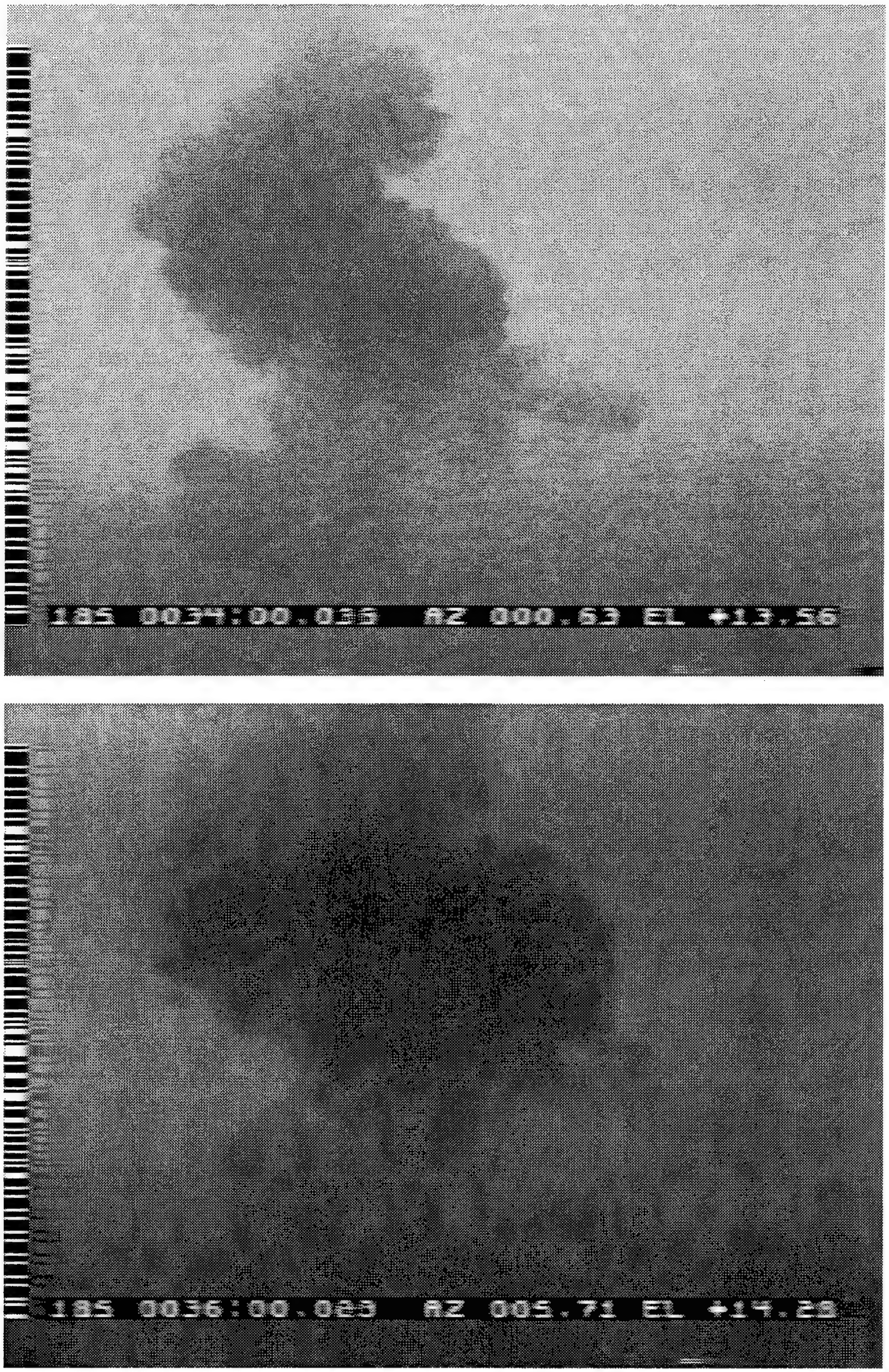


Figure 5. Visible imagery from SLC-34 Site with elevated ground cloud in FOV: (a) Upper image at T+04:00 (mm:ss) with ground cloud almost filling the vertical FOV; (b) Lower image at T+06:00 (mm:ss) with lower portion of ground cloud dissipating.

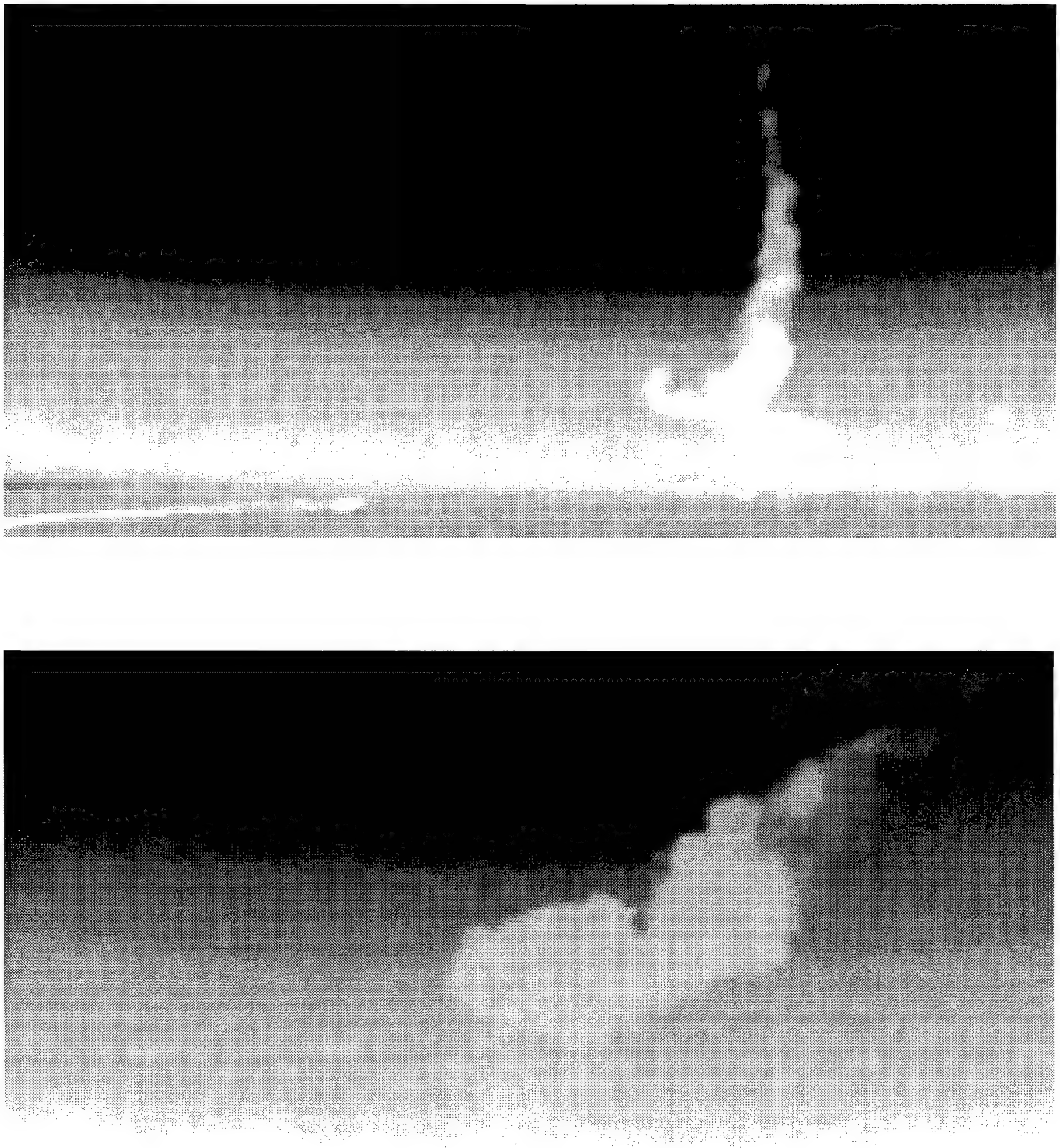


Figure 6. Infrared imagery from UCS-07 with evolving ground cloud in FOV: (a) Upper at T+01:00 (mm:ss) with ground structures evident in the FOV; (b) Lower at T+06:00 (mm:ss) with contrast adjusted to emphasize upper portion of ground cloud.

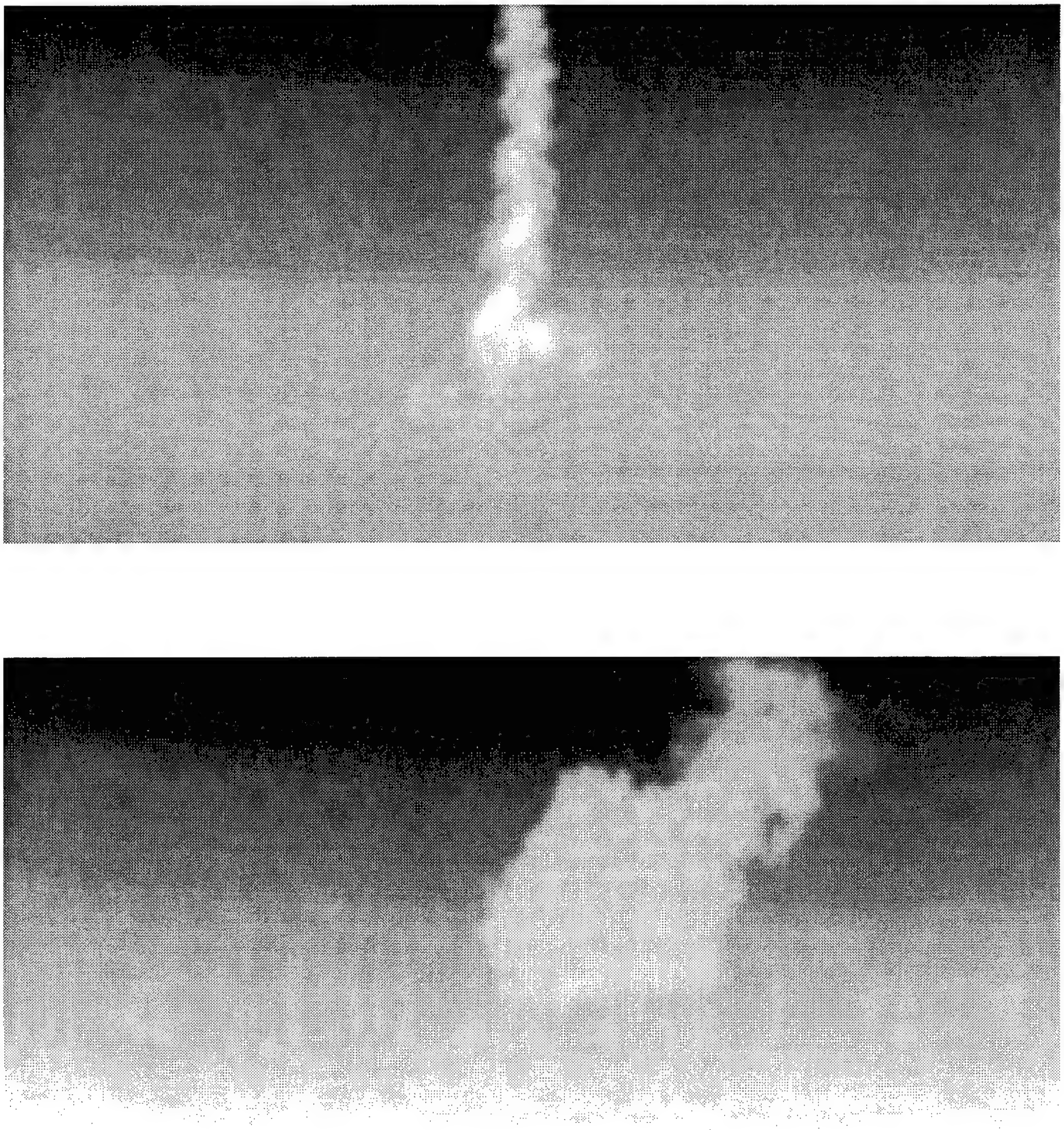


Figure 7. Infrared imagery from static test viewing site with evolving ground cloud in FOV: (a) Upper at T+01:00 (mm:ss) with the tree line evident in the lower portion of the image; (b) Lower at T+06:00 (mm:ss) with contrast adjusted to emphasize upper portion of ground cloud.

2.5.2 Cloud Rise Times and Stabilization Heights

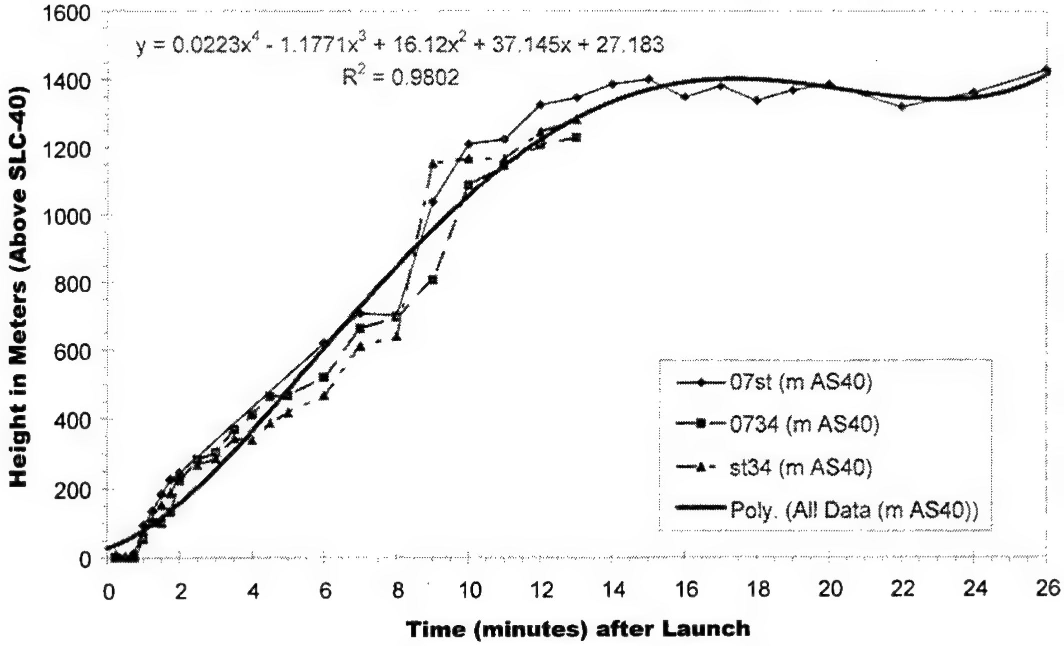
Figures 8 through 10 present the imagery-derived time-dependent altitude for the "bottom," the "middle," and the "top" of the ground cloud. These plots document the rise time and the stabilization height for each portion of the cloud. In these plots, all data are plotted as height in meters above SLC-40 (i.e., m AS40). The analyst used the **PLMTRACK Box Method** separately for each of three pairs of imagery. In the upper plots, symbols identify the imagery-pairs used to track the cloud as defined in Table 2.

For clarity, all plots include a polynomial fit to the combined data (i.e., all data independent of the imagery pair). It is apparent from the upper plots that no imagery pair biases the data significantly. Therefore, in the lower plots, there is no differentiation based upon the imagery pairs. The lower plots also include lines documenting the average stabilization height as well as the $\pm 3\sigma$ error bars for the stabilization height.

The variances (R^2) of the polynomial fits to the data indicate that the fits are very good. A polynomial fit was used in these figures as a convenient method to permit the representation of cloud overshoot and subsequent damped oscillation around the stabilization height. To be consistent with REEDM, stabilization time and height refer to the first maximum in these fits. REEDM predicts that the cloud goes through damped oscillatory motion with a period of $2\pi/S^{1/2}$, where S is the static stability parameter [Ref. 1, Eq. (7)].[2] Sensitivity of REEDM predictions to input parameters has been examined by Womack.[3] Careful imaging of launch ground clouds under a variety of meteorological conditions is a vital element in REEDM evaluation.

Table 2. Labels Used to Identify Imagery-Pairs Used for PLMTRACK

Label	Imagery Site 1	Imagery Site 2
07st	UCS-07 Infrared	Static Infrared
0734	UCS-07 Infrared	SLC-34 Visible
st34	Static Infrared	SLC-34 Visible



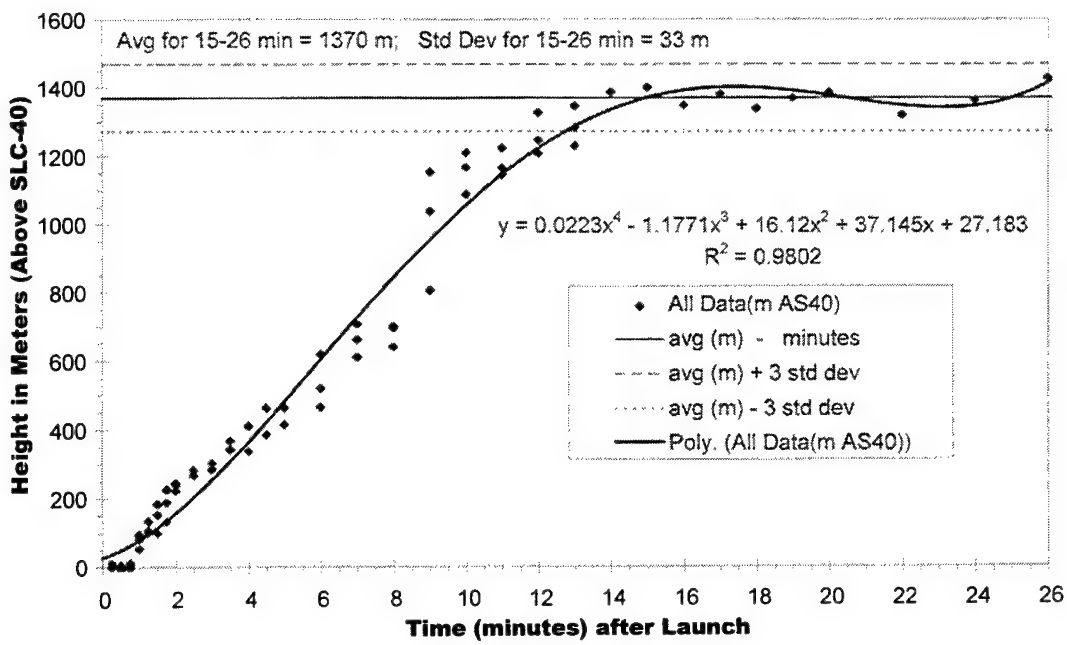


Figure 8. Cloud rise plots for the bottom of the #K2 ground cloud as determined using the PLMTRACK Box Method with pairs of imagery. The upper plots identify the imagery pairs used by PLMTRACK. The lower plots treat all data, independent of the imagery pairs, as one data set. Lines document the fourth-order polynomial fit to the combined data, the average stabilization height, and the 3σ error bands for the stabilization height. The variance (R2) of 0.9802 indicates the high quality of the polynomial fit.

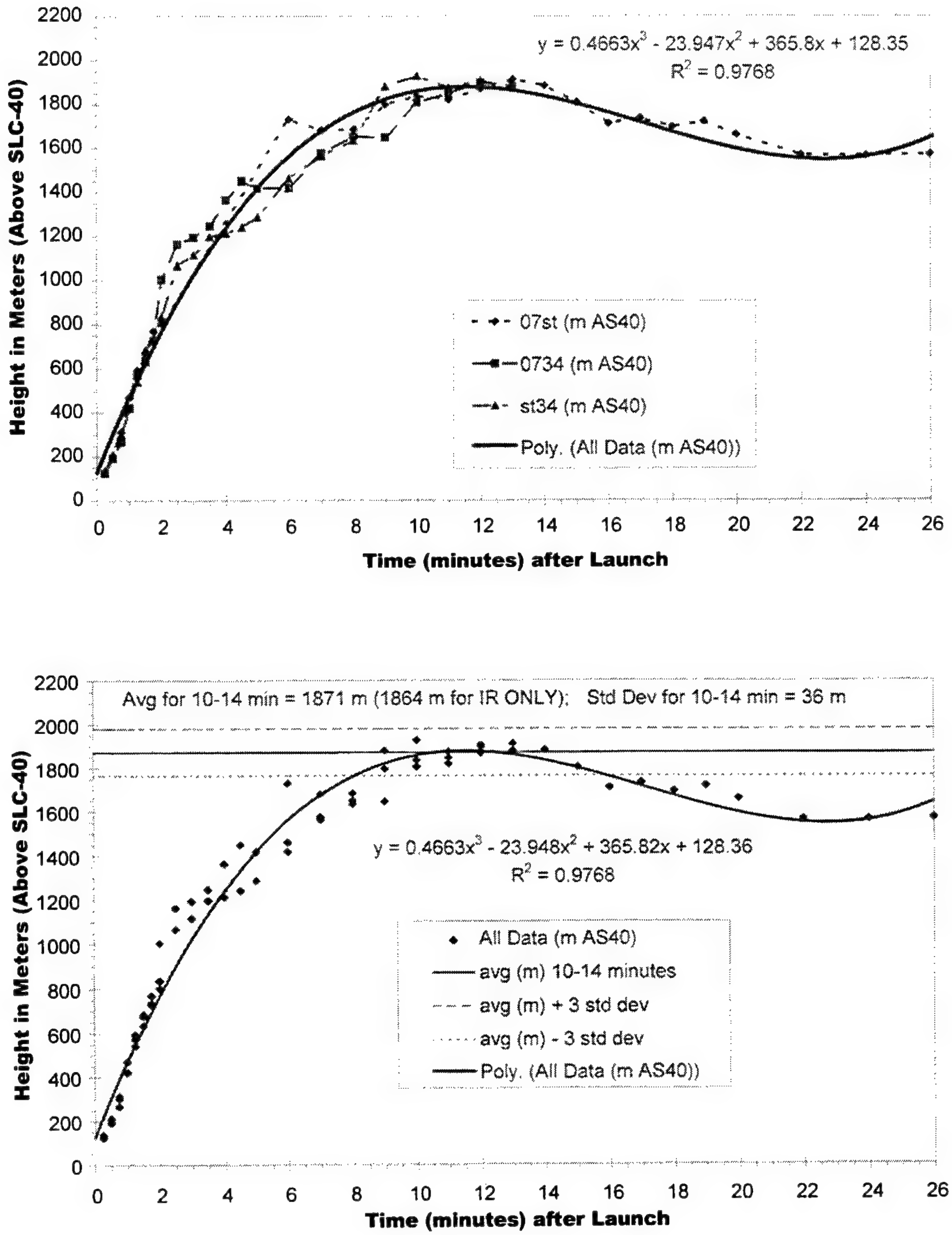
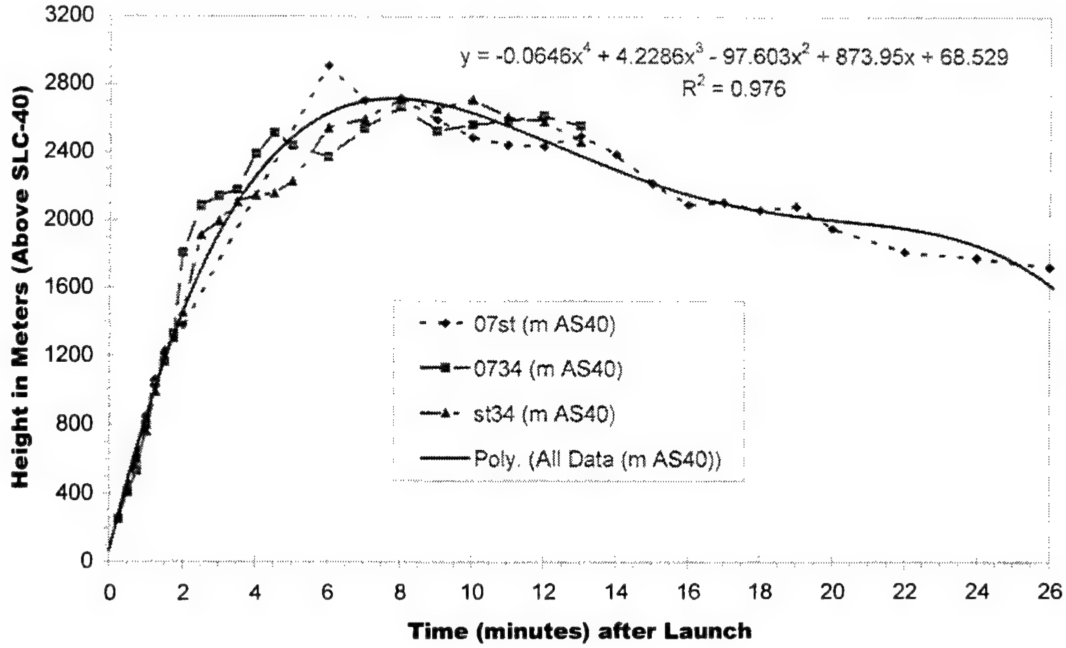


Figure 9. Cloud rise plots for the middle of the #K2 ground cloud as determined using the PLMTRACK Box Method with pairs of imagery. The upper plots identify the imagery pairs used by PLMTRACK. The lower plots treat all data, independent of the imagery pairs, as one data set. Lines document the third-order polynomial fit to the combined data, the average stabilization height, and the 3σ error bands for the stabilization height. The variance (R2) of 0.9768 indicates the high quality of the polynomial fit.



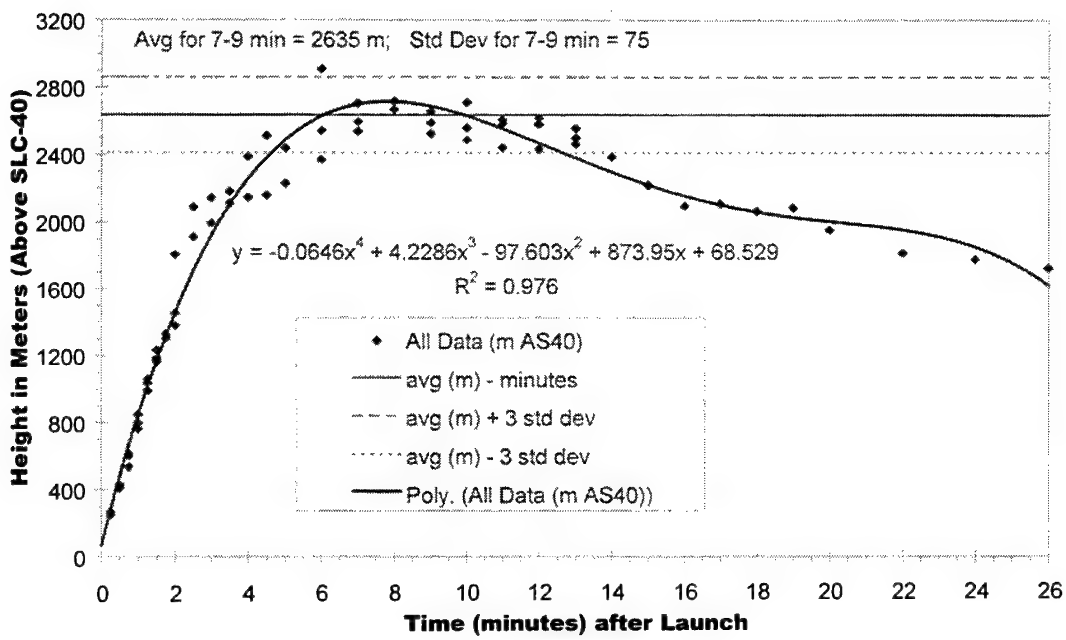


Figure 10. Cloud rise plots for the top of the #K2 ground cloud as determined using the PLMTRACK Box Method with pairs of imagery. The upper plots identify the imagery pairs used by PLMTRACK. The lower plots treat all data, independent of the imagery pairs, as one data set. Lines document the fourth-order polynomial fit to the combined data, the average stabilization height, and the 3σ error bands for the stabilization height. The variance (R2) of 0.9760 indicates the high quality of the polynomial fit.

2.5.3 Comparison of REEDM Prediction to Imagery Data—Stabilization Height

Figure 11 presents the imagery-derived heights for the ground cloud's top, middle, and bottom plotted as a function of time following the launch. It can be seen that the measured stabilization height of the middle of the ground cloud (1871 m AGL ±36 m) is 72% higher than predicted (1087 m AGL) by the T-0.8h REEDM modeling run (Appendix A). The time required to reach the stabilization height (approximately 10–14 min documented by quantitative imagery) is 4 to 46% slower than the 9.6 min predicted by the T-0.8h REEDM modeling run.

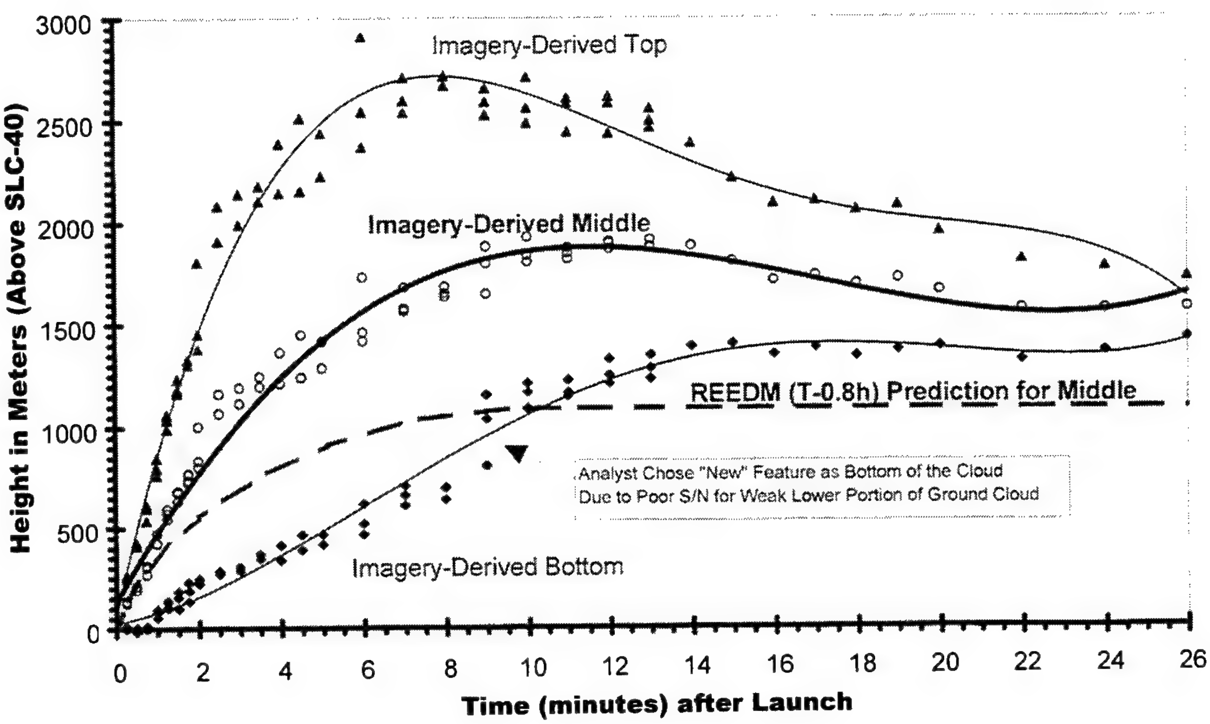


Figure 11. Imagery-derived stabilization heights compared to T-0.8h REEDM prediction. The plot includes the quantitative imagery data for the top, middle, and bottom of the ground cloud. For comparison, the plot also includes the T-0.8h REEDM modeling run prediction for the cloud's middle. The predicted stabilization height was 1087 m AGL while the imagery-derived stabilization height was 1871 ±36 m AGL.

2.5.4 Comparison of REEDM Prediction to Imagery Data—Bearing and Speed

Figures 12 and 13 document the plots used to derive the ground cloud's bearing and speed, respectively, from the quantitative imagery data. The **PLMTRACK Box Method** does not yield independent values for the top, middle, and bottom of the cloud. We have chosen to plot the data for the middle of the ground cloud.

Figure 12 plots the Cartesian coordinates for the middle of the ground cloud as distance north/south and distance east/west of SLC-40. Due to poor trigonometry at early times, the data derived from UCS-07 imagery paired with SLC-34 imagery (i.e., labeled 0734 on plot) is not accurate until the ground cloud moves out from between these two imagery sites. After 2 min (i.e., when the cloud has moved ~ 1000 m to the east of SLC-40), the trigonometry is reasonable for all pairs of imagery. Therefore, the line fits the combined data (i.e., independent of imagery pair) for times longer than 2 min. The slope of this least squares linear fit to the combined data documents a 248° rawinsonde equivalent bearing for the ground cloud during its rise and subsequent to its stabilization.

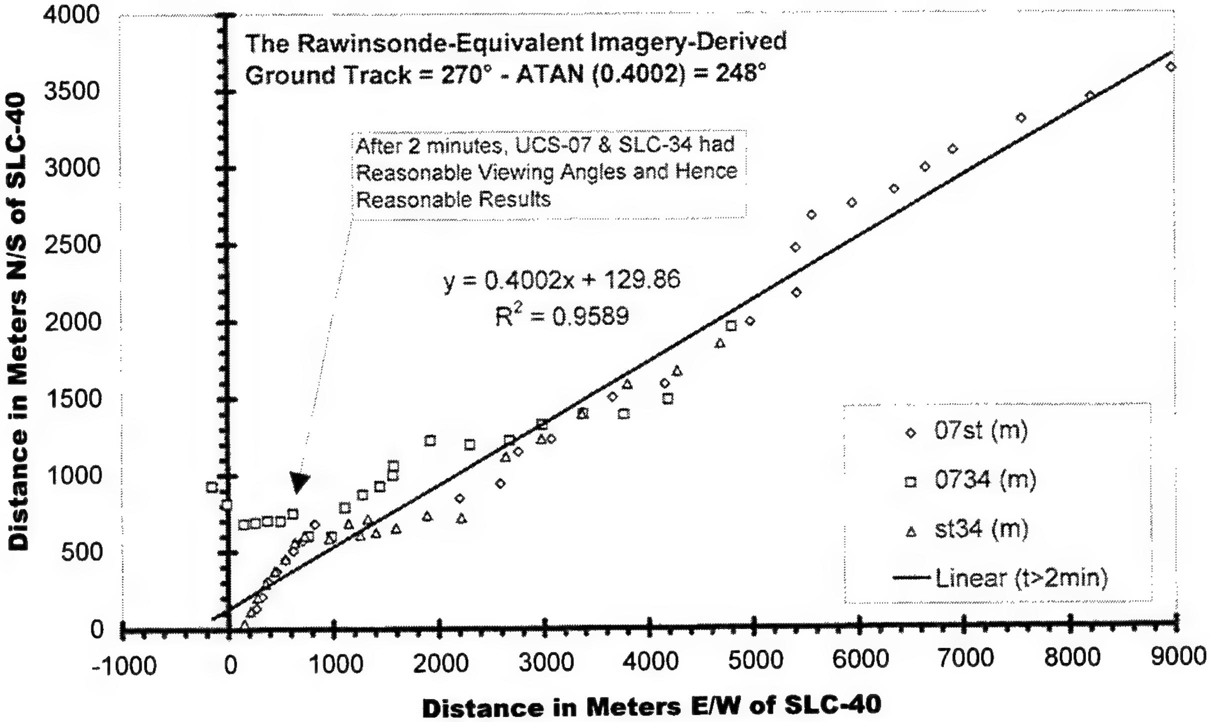


Figure 12. Cartesian plot documenting the imagery-derived ground cloud bearing for the #K2 mission. The symbols document the PLMTRACK imagery pairs used to derive the data. The line is a linear fit to the combined data (i.e., independent of imagery pair) for times after 2 min. Therefore, the ground cloud moved along a bearing of 248° during rise and after stabilization.

In this report, the angles conform to the convention of rawinsonde wind vectors (the angle from which the wind originates that would push the cloud into its imaged position). Thus, the angles are related by

$$\vartheta = 180 + \Phi, \tag{2}$$

where ϑ is the equivalent rawinsonde wind angle, and Φ is the measured polar angle of the cloud relative to SLC-40 and clockwise of true north. For example, when the cloud is due east of SLC-40, Φ is 90°, and ϑ is 270°.

Figure 13 plots the ground distance from the middle of the exhaust cloud to SLC-40 against time after launch. As with the cloud track (i.e., Figure 12), poor trigonometry at early times is apparent for the UCS-07 imagery when paired with SLC-34 imagery (i.e., labeled 0734 on plot). After 2 min (i.e., when the cloud has moved ~ 1000 m to the east of SLC-40), the trigonometry is reasonable for all pairs of imagery. Therefore, the line fits the combined data (i.e., independent of imagery pair) for times longer than 2 min. The slope of this least squares linear fit to the combined data documents a 6.2 m/s speed for the ground cloud during its rise and subsequent to its stabilization.

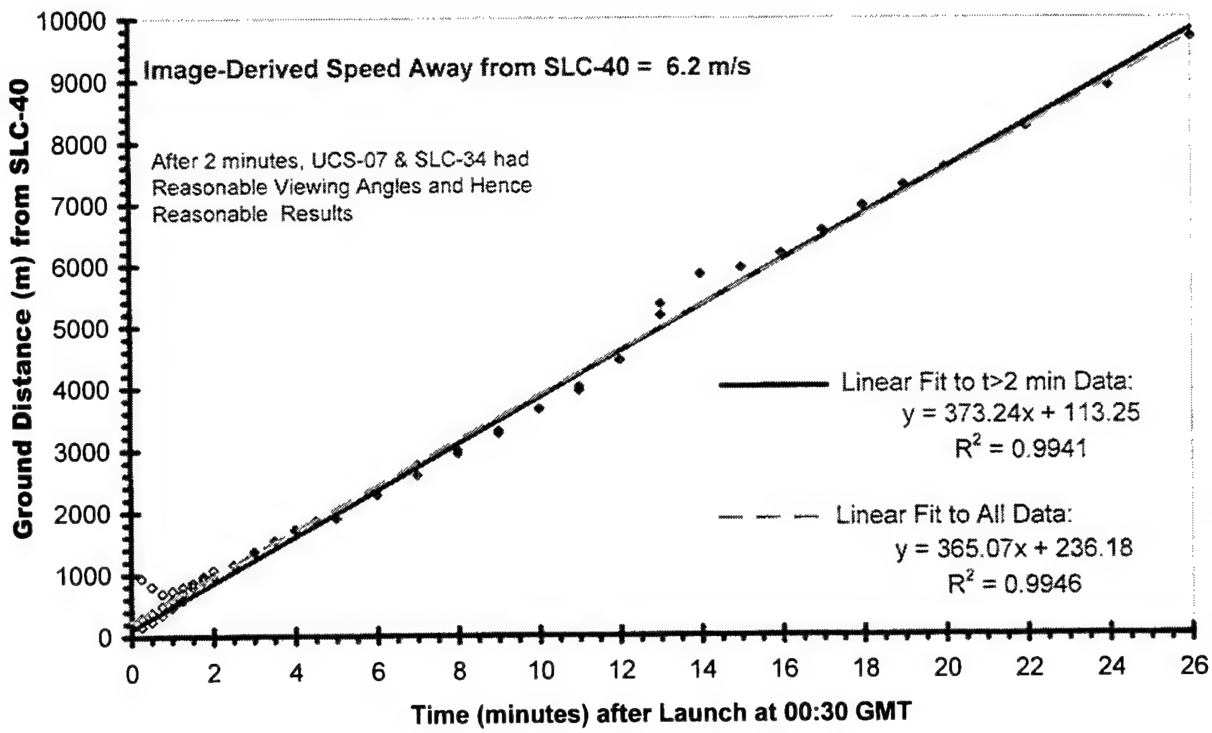


Figure 13. Time plot of the ground distance from SLC-40 for the #K2 exhaust cloud. The symbols document the PLMTRACK imagery pairs used to derive the data. The line is a linear fit to the combined data (i.e., independent of imagery pair) for times after 2 min. Therefore, the ground cloud moved at a steady speed of 6.2 m/s during rise and after stabilization.

2.5.5 Comparison of REEDM Prediction to Imagery Data—Summary Table

Table 3 summarizes the imagery derived, the T-0.8h rawinsonde measured, and the T-0.8h REEDM-predicted data for the #K2 ground cloud. Several conclusions can be derived from review of the contents of this table and from previous discussions:

(1) imagery-derived stabilization height (1871 m AGL) is 72% higher than the T-0.8h REEDM-predicted stabilization height (1087 m AGL);

(2) the imagery-derived stabilization time (10–14 min) is 4 to 46% slower than the T-0.8h REEDM-predicted stabilization time (9.6 min);

(3) the imagery-derived bearing (248°) falls between REEDM's predictions for the bearing (241°) to maximum ground concentration and the bearing (253°) at the stabilization height;

(4) the imagery-derived cloud speed (6.2 m/s) is 22% faster than the 5.1 m/s wind measured by rawinsonde at the imagery-derived height of the middle of the ground cloud; and

(5) the imagery-derived cloud speed (6.2 m/s) is 44% faster than the 4.3 m/s average wind for the second mixing layer (i.e., REEDM's predicted speed for the stabilized ground cloud).

Table 3. Summary for #K2 Launch Cloud Data Derived from Visible and Infrared Imagery, T-0.8h Rawinsonde Sounding Data and T-0.8h REEDM Predictions

Attribute	Feature	Imagery (IR & Vis)	Rawinsonde (T-0.8h)	REEDM 7.07 (T-0.8h)
Height (m AGL)	Top	2635	#N/A	1824
Above SLC-40	Middle	1871	#N/A	1087
(SLC-40 = 7 m MSL)	Bottom	1370	#N/A	428
Time (min)	Top	7–9	#N/A	#N/A
After Launch	Middle	10–14	#N/A	9.6
	Bottom	15–26	#N/A	#N/A
Bearing (deg)	Top	#N/A	292	#N/A
(rawinsonde)	Middle	248.0	278	253
	Bottom	#N/A	251	#N/A
Speed (m/s)	Top	#N/A	2.6	#N/A
Away From	Middle	6.2	5.1	4.3
SLC-40	Bottom	#N/A	5.7	#N/A

2.5.6 Imagery-Derived Cross-Wind Growth Rate

The imagery from the Static Test Viewing Site documented the growth in the cross-wind width of the ground cloud as a function of time and distance from the pad. The cloud moved to the east-northeast of SLC-40, which was almost directly away from the Static Test Viewing site, which was to the west-southwest of SLC-40. Figure 14 presents a plot of the ground cloud's cross-wind width (W) against ground distance (D) from SLC-40. The slant range (R) from the Static Test Viewing Site to the middle of the ground cloud is also plotted in Figure 14. Figure 15 presents a

plot of the ground cloud's cross-wind width against time after launch. The cross-wind width was calculated from the azimuthal width of the cloud as seen from Static Test Viewing site and from the triangulated position of the middle of the ground cloud relative to Static Test Viewing site using the following relationship:

$$W(t) = 2R(t)TAN(dAZ(t) / 2),$$

where W(t) is the cross-wind width (meters) of the cloud, R(t) is the slant range (meters) of the middle of the ground cloud from the Static Test Viewing site, and dAZ(t) is the azimuthal cross-wind width (degrees) of the cloud as observed from the Static Test Viewing site. All of these parameters vary with time (t). We used USC-07 Site's infrared imagery paired with Static Test Viewing Site's infrared imagery to measure the cloud's position. The cloud's cross-wind width (dAZ) was measured using only Static Test Viewing Site imagery. The growth in cross-wind width (m) as plotted in Figure 14 and Figure 15 is fit by linear regression for early times by the following formulas:

$$W = 0.4298D + 647$$

$$W = 160.54t + 724$$

Therefore, the imagery data documents an initial width of 647 to 724 m for the cloud, based upon extrapolation to launch time. Since the rate of growth changes at early times, as revealed both by Figure 14 and Figure 15, such a linear extrapolation overestimates the initial radius of the cloud. It is also apparent from these plots that the observable cross-wind width collapses at later times. This is a result of poor signal-to-noise ratio at later times and at greater distances from the Static Test Viewing Site. These data suggest good signal-to-noise till about 14 min after launch, well after stabilization.

2.6 Summary and Conclusions

The Titan IV #K2 mission was launched successfully from the Eastern Range (SLC-40) at 2030 EDT (0030 GMT) on 02 July 1996. Personnel from The Aerospace Corporation deployed three VIRIS platforms (using both visible and infrared imagery) to monitor the event and to track the evolution of the solid rocket motor exhaust cloud. The three chosen sites (UCS-7, SLC 34, and the Static Test Viewing Site) were located to the north-northwest, south-southeast, and west-southwest relative to SLC-40. The VIRIS systems imaged the ground cloud for 34 min after the launch. When combined with the AZ/EL readings and the IRIG-B time data, the **PLMTRACK Box Method** documented the rise, stabilization, growth, speed, and bearing of the ground cloud for 26 min after the launch. The imagery documented that the ground cloud remained within the first mixing layer throughout the tracking period. This quantitative imagery data for the #K2 ground cloud will be extremely useful for tuning current and future dispersion models.

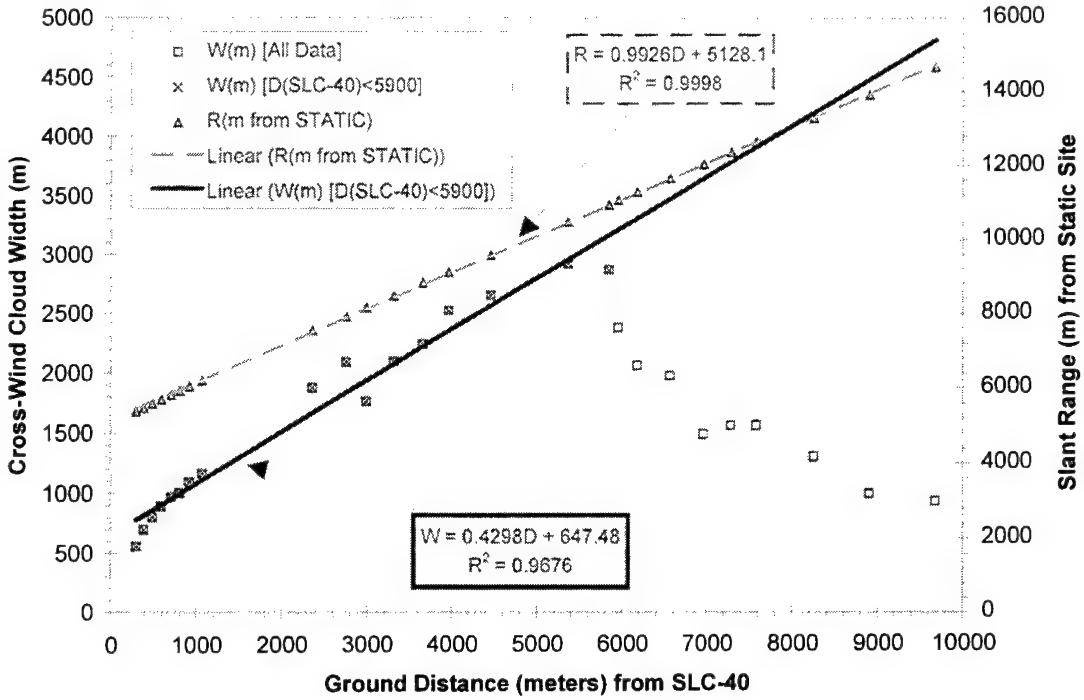


Figure 14. Plot of the #K2 ground cloud's cross-wind width (W) against ground distance (D) from SLC-40 and with slant range (R) from static test viewing site.

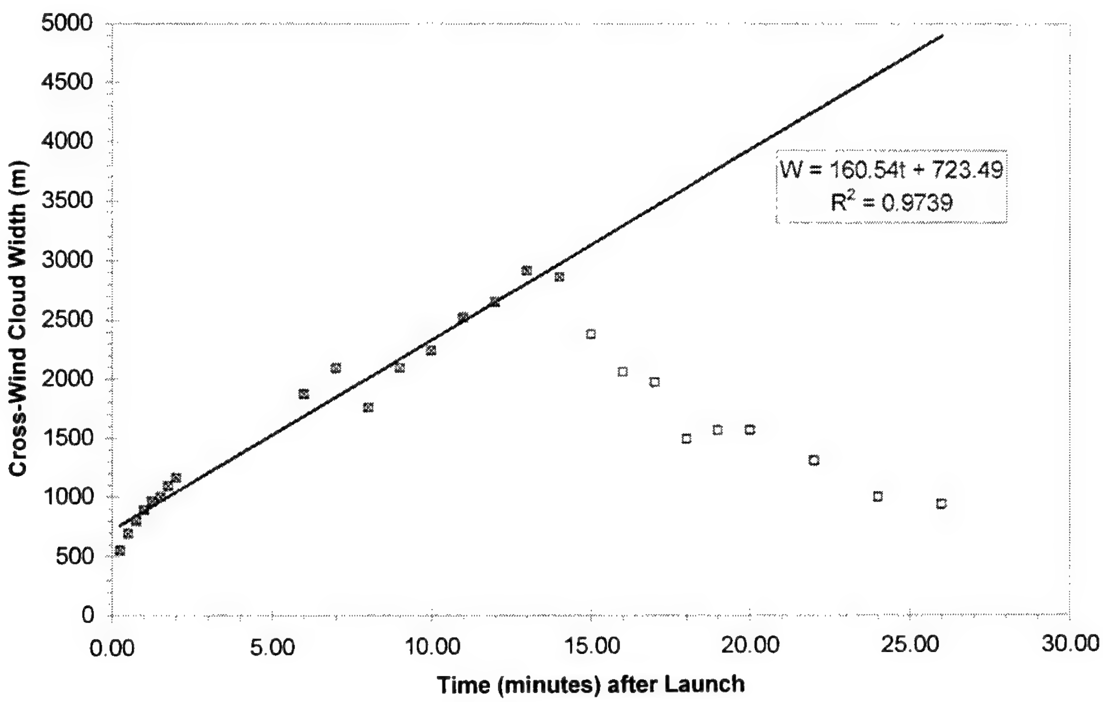


Figure 15. #K2 ground cloud's cross-wind width (W) plotted against time (t) after launch.

The definition of the #K2 exhaust cloud's geometric features is complicated by its three-dimensional shape (i.e., not spherical). However, the imagery successfully documented this complex shape as the cloud evolved (i.e., asymmetric ejection from the exhaust duct, rapid rise of the hot ground cloud, shear between the high-altitude launch column and the top of the ground cloud, and shear between the top and bottom of the ground cloud). The analyst included only the portions of the exhaust cloud that became incorporated into the stabilized ground cloud as revealed by both visible and infrared imagery.

Analysis of the imagery data presented in this report has focused on determining parameters that are directly comparable to REEDM predictions. For Titan IV #K2 launch, T-0.8h REEDM predictions were substantially different from those measured by imagery. According to the quantitative visible and infrared imagery from three imagery sites, the ground cloud took 10–14 min to stabilize (4 to 46% slower than predicted), stabilized at 1871 m AGL (72% higher than predicted), moved in a east-northeasterly direction (similar to prediction), and moved at an average speed of 6.2 m/s (44% faster than predicted). Both the speed and the stabilization height are important parameters that drive the hazard zone predictions. The predicted ground-level concentrations are inversely related to the third power of the stabilization height.

The Aerospace Corporation has imaged twelve other Titan IV launches as part of the Model Validation Program. All of the available Titan IV imagery documents that REEDM consistently underestimates the stabilization height of the ground cloud. Such overly conservative REEDM predictions can result in unnecessary launch holds at a considerable cost to the Air Force. Additional Titan IV exhaust cloud data are needed to validate and to tune current and future dispersion models for both ranges (Vandenberg AFB and CCAS) and for the various meteorological conditions associated with round-the-clock and year-round launch schedules.

3. Ground HCl Sampling

3.1 Introduction

The NASA Kennedy Space Center's Toxic Vapor Detection and Contamination Monitoring Laboratory supported the exhaust plume measurements for the #K2 launch in several ways. In support of planned mobile ground sampling, Interscan monitors and a Geomet HCl monitor were prepared and calibrated in addition to an Army HCl instrument under evaluation. Finally, ground HCl dosimeters were prepared, deployed, recovered, and read to determine the ground deposition of HCl resulting from the ground cloud movement. These efforts were carried out under the leadership of Paul Yocum and sponsored by the 45th Space Wing Bioenvironmental Engineering Branch under LtCol Rusden, and are all covered in this section of the report.

3.2 Equipment Preparation

The high-flow Interscan HCl monitors were charged and calibrated immediately prior to deployment by the mobile monitoring teams. The Geomet HCl monitor and a HCl monitor designed and built by the Army research lab and under test by the TVD lab were prepared, calibrated, and deployed by one of the mobile monitoring teams for suitability field testing.

3.3 Dosimeter Monitoring

The primary goal for HCl dosimeter monitoring during this Titan IV launch was collection of ground-level data from around the launch facility. Dosimeters were fabricated one day before the launch to ensure best results. Dosimeters were provided to Air Force personnel for near-field placement around the launch complex. Ten dosimeters were placed around Complex 40 the day of the launch. Six were placed on the perimeter fence 5 ft above ground level approximately 600 ft from the vehicle. Four dosimeters were placed on structures inside the fence, one on each lightning tower approximately 150 ft from the vehicle. The approximate locations of the near-field dosimeters are shown in Figure 16.

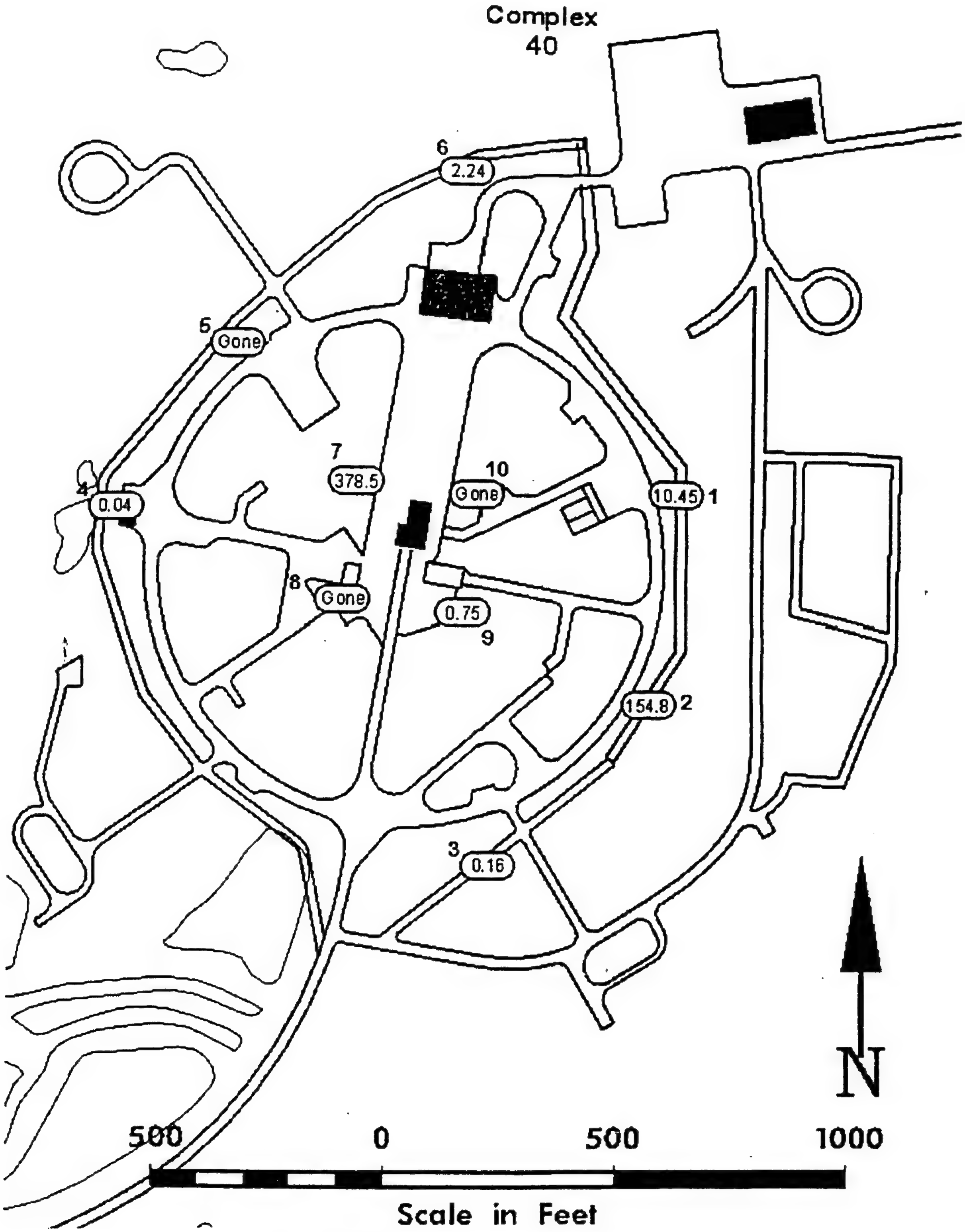


Figure 16. Dosimeter placement and dose.

3.4 Ground-Level Monitoring Results

Of the ten dosimeters placed in the vicinity of launch Complex 40 inside the perimeter fence, three were unrecoverable. The remaining dosimeters indicated a measurable amount of HCl. The results are shown in Table 4. The highest doses were recorded at the lightning towers, which are the closest locations to the launch vehicle. From the HCl levels recorded by the dosimeters on the perimeter fence, it appears that the ground-level HCl was concentrated east of the launch tower. Dosimeters placed at the same sites during previous launches also detected HCl at the perimeter fence locations.

Table 4. Near-Field HCl Dosimeter Location, Stain Measurements, and Doses

Site Number	Dosimeter Location	LOS (In)	Calc Dose (ppm min)
1	East perimeter fence	0.24	10.45
2	East perimeter fence	0.911	154.78
3	SE perimeter fence	0.03	0.16
4	West perimeter fence	0.015	0.04
5	NW perimeter fence	Not recovered	0.00
6	NW perimeter fence	0.112	2.24
7	NW Lightning tower	1.418	378.49
8	SW lightning tower	Not recovered	0.00
9	SE lightning tower	0.065	0.75
10	NE lightning tower	Not recovered	0.00

3.5 Mobile Monitoring Teams Results

The Army-designed HCl monitor and the Geomet HCl monitor from airborne monitoring were used by the same mobile monitoring team and did not detect HCl. Three Interscan real-time HCl monitors provided to the Air Force mobile HCl monitoring teams did not detect the presence of HCl. The Geomet HCl monitor varies in output too much to be used for low-level HCl ground monitoring. The Army HCl monitor has possibilities for future ground monitoring and is a fairly rugged unit. The Army unit like the Geomet is a wet chemistry type monitor and must be mounted to preclude the possibility of tipping in rough terrain.

References

1. R. N. Abernathy, R. F. Heidner III, B. P. Kasper, and J. T. Knudtson, "Visible and Infrared Imagery of the Launch of the Titan IV #K23 from Cape Canaveral Air Force Station on 14 May 1995," TOR-96(1410)-1, The Aerospace Corporation, El Segundo, CA (15 September 1996).

2. J. R. Bjorklund, "User's Manual for the REEDM Version 7 (Rocket Exhaust Effluent Diffusion Model) Computer Program, Vol. I," TR-90-157-01, AF Systems Command, Patrick AFB, FL (April 1990).

3. J. M. Womack, "Rocket Exhaust Effluent Diffusion Model Sensitivity Study," TOR-95(5448)-3, The Aerospace Corporation, El Segundo, CA (May 1995).

Appendix A—REEDM Version 7.07 Predictions for the #K2 Mission

[The material in this section was contributed by R. N. Abernathy of the Environmental Monitoring and Technology Department of The Aerospace Corporation's Space and Environment Technology Center.]

This Appendix includes REEDM version 7.07 runs for impact at both the surface (0 m AGL, 7 m MSL) and stabilization height (predicted by REEDM). We include the plots of the rawinsonde meteorological data, the predicted maximum concentration versus downwind distance, and the predicted concentration isopleths overlayed on a range map. These plots are followed by the detailed REEDM report for that run.

Stabilization Height Predictions

The following figures and table are the REEDM version 7.07 output for the stabilization height run. These predictions were compared with actual #K2 ground cloud observations in Section 2 for the quantitative imagery. The first page of the REEDM output is its listing of errors and is not included in this appendix.

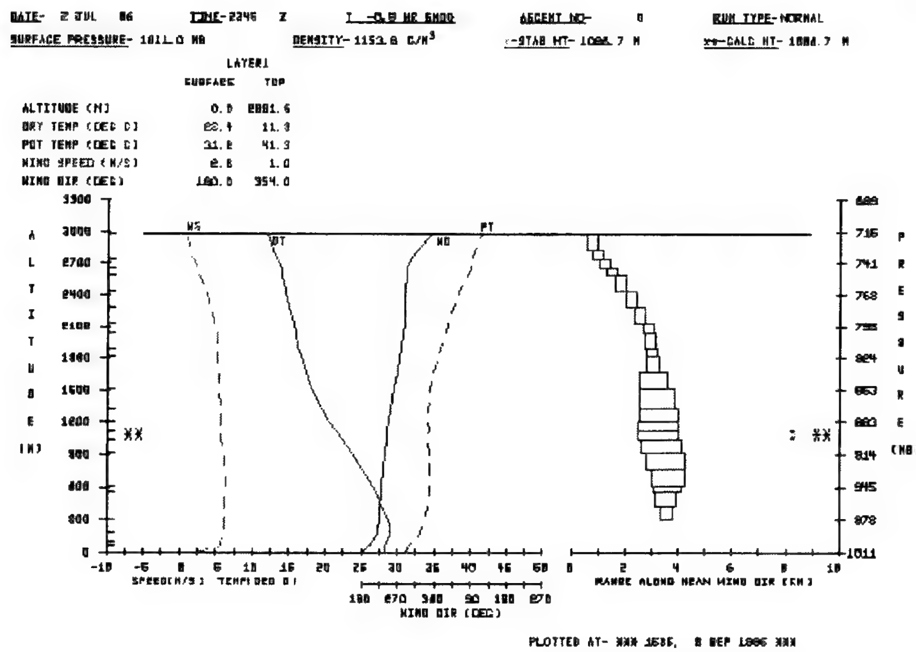


Figure A1. Meteorological output plot from REEDM Version 7.07 for #K2 mission using T-0.8h rawinsonde data.

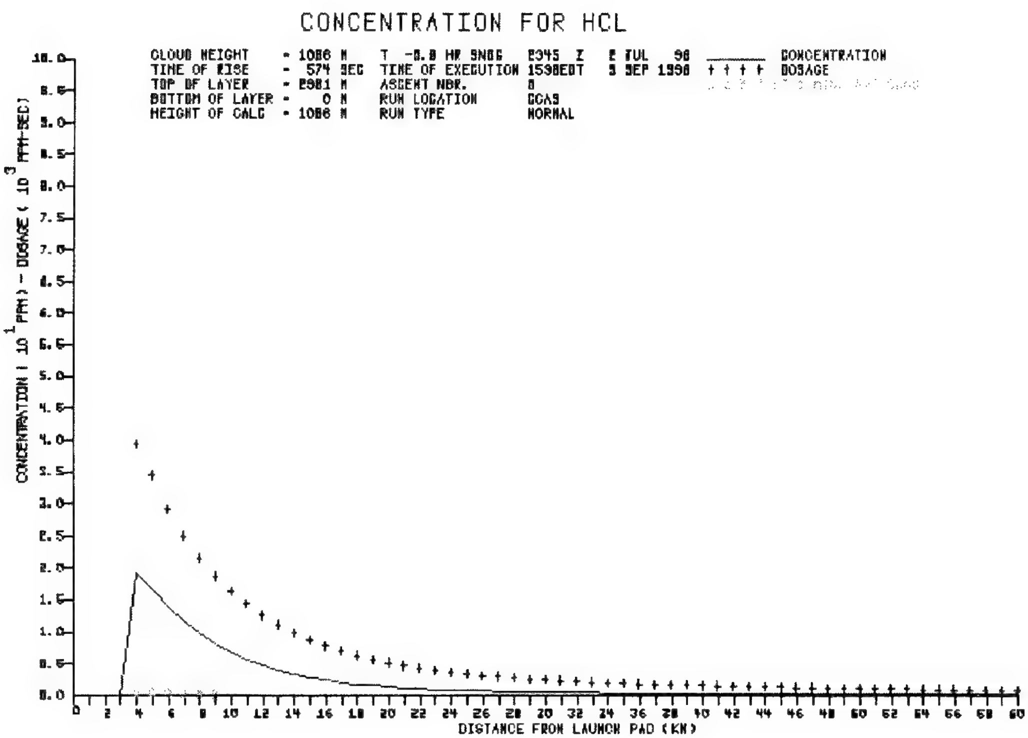


Figure A2. HCl stabilization height concentration predictions from REEDM Version 7.07 for #K2 mission using T-0.8h rawinsonde data.

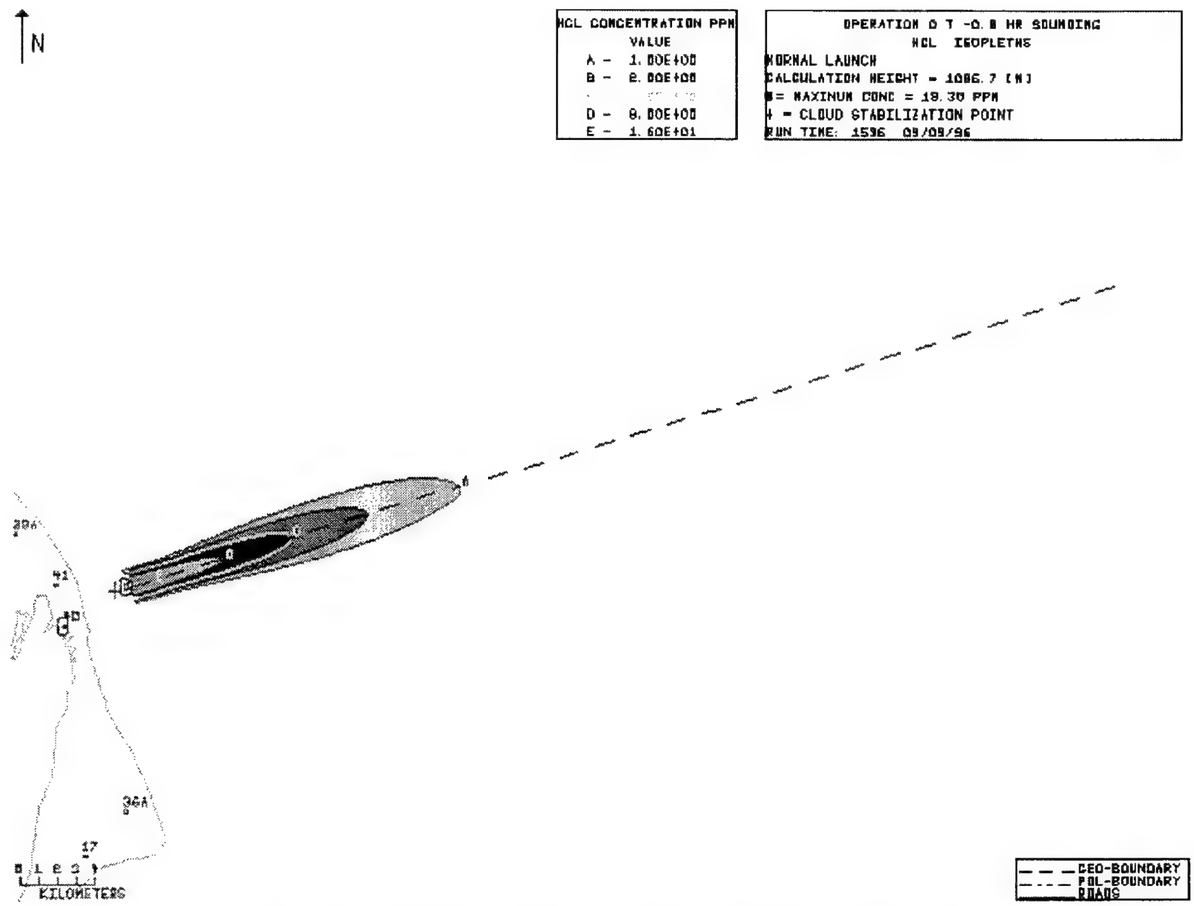


Figure A3. HCl stabilization height concentration isopleth predictions from REEDM Version 7.07 for #K2 mission using T-0.8h rawinsonde data.

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1****************************************************************************
              ROCKET EXHAUST EFFLUENT DIFFUSION MODEL REEDM        PAGE    2
                         VERSION 7.07 AT CCAS
                         1536 EDT  9 SEP 1996
                   launch time:  2030 EDT 02 JUL 1996
     RAWINSONDE ASCENT NUMBER      0, 2345   Z  2 JUL   96  T  -0.8 HR
****************************************************************************

                       ----- PROGRAM OPTIONS -----

 MODEL                                                         CONCENTRATION
 RUN TYPE                                                        OPERATIONAL
 WIND-FIELD TERRAIN EFFECTS MODEL                                       NONE
 LAUNCH VEHICLE                                                     TITAN IV
 LAUNCH TYPE                                                          NORMAL
 LAUNCH COMPLEX NUMBER                                                    40
 TURBULENCE PARAMETERS ARE DETERMINED FROM               CLIMATOLOGICAL DATA
 SURFACE CHEMISTRY MODEL                              absorption coefficient
 SPECIES      SURFACE FACTOR                               HCL         0.000
 CLOUD SHAPE                                                      ELLIPTICAL
 CALCULATION HEIGHT                                            STABILIZATION
 PROPELLANT TEMPERATURE (DEG. C)                                       28.38
 CONCENTRATION AVERAGING TIME (SEC.)                                 3600.00
 mixing layer reflection coefficient (RNG- 0 TO 1,no reflection=0)    1.0000
 DIFFUSION COEFFICIENTS                                  LATERAL      1.0000
                                                         VERTICAL     1.0000
 VEHICLE AIR ENTRAINMENT PARAMETER                       GAMMAE       0.6400
 DOWNWIND EXPANSION DISTANCE (METERS)                    LATERAL      100.00
                                                         VERTICAL     100.00

                         ----- DATA FILES -----

                              INPUT FILES
 RAWINSONDE FILE                                               k02_2345.raw
 DATA BASE FILE                                                rdmbase.ksc

                              OUTPUT FILES
 PRINT FILE                                                    k02_2345.stb
 PLOT FILE                                                     k02_2345.ptb
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1***

ROCKET EXHAUST EFFLUENT DIFFUSION MODEL REEDM PAGE 3

VERSION 7.07 AT CCAS

1536 EDT 9 SEP 1996

launch time: 2030 EDT 02 JUL 1996

RAWINSONDE ASCENT NUMBER 0, 2345 Z 2 JUL 96 T -0.8 HR

****

----- METEOROLOGICAL RAWINSONDE DATA -----

RAWINSONDE MSS/MSS
TIME- 2345 Z DATE- 02 JUL 96
ASCENT NUMBER 0

----- T -0.8 HR SOUNDING -----

MET. LEV. NO.	ALTITUDE MSL (FT)	GND (FT)	GND (M)	WIND DIR (DEG)	WIND SPEED (M/S)	(KTS)	TEMP	AIR PTEMP (DEG C)	DPTEMP	AIR PRESS (MB)	AIR RH (%)	H M	INT-ERP
1	16	0.0	0.0	180	2.6	5.0	28.4	31.2	25.4	1011.0	84.0		
2	66	50.0	15.2	186	3.3	6.5	28.4	31.3	25.4	1009.3	83.8		**
3	116	100.0	30.5	191	4.1	8.0	28.4	31.4	25.4	1007.5	83.8		**
4	166	150.0	45.7	197	4.9	9.5	28.3	31.5	25.3	1005.8	83.8		**
5	216	200.0	61.0	202	5.7	11.0	28.3	31.7	25.3	1004.1	84.0		
6	276	260.5	79.4	205	5.7	11.0	28.4	31.9	25.0	1002.0	81.6		**
7	337	321.0	97.8	207	5.7	11.0	28.5	32.1	24.6	1000.0	79.0		
8	430	413.7	126.1	211	5.8	11.3	28.7	32.4	24.0	996.9	75.8		**
9	522	506.3	154.3	216	6.0	11.7	28.9	32.8	23.4	993.7	72.3		**
10	615	599.0	182.6	220	6.2	12.0	29.1	33.2	22.8	990.6	69.0		
11	808	791.5	241.2	222	6.2	12.0	28.9	33.5	22.2	984.1	67.2		**
12	1000	984.0	299.9	224	6.2	12.0	28.7	33.8	21.6	977.7	66.0		
13	1419	1403.0	427.6	228	6.2	12.0	27.9	34.0	20.7	963.7	65.3		**
14	1838	1822.0	555.3	231	6.2	12.0	27.0	34.3	19.8	950.0	65.0		
15	2000	1984.0	604.7	232	6.4	12.4	26.6	34.3	19.6	944.8	65.0		
16	2500	2484.0	757.1	235	6.2	12.1	25.1	34.3	19.0	928.6	68.7		**
17	3000	2984.0	909.5	238	6.1	11.8	23.7	34.3	18.3	912.8	72.0		
18	3399	3383.0	1031.1	242	5.7	11.0	22.4	34.2	18.0	900.0	76.0		
19	3719	3703.0	1128.7	245	5.7	11.0	21.5	34.2	17.9	890.2	80.0		
20	4000	3984.0	1214.3	248	5.7	11.0	20.6	34.2	17.9	881.5	84.0		
21	4359	4343.0	1323.7	251	5.7	11.0	19.5	34.2	17.8	870.4	90.0		
22	5000	4984.0	1519.1	261	5.4	10.5	18.1	34.4	15.9	851.0	87.0		
23	5500	5484.0	1671.5	268	5.3	10.3	17.4	34.9	13.7	836.0	79.5		**
24	6000	5984.0	1823.9	275	5.2	10.1	16.6	35.4	11.5	821.3	72.0		
25	6241	6225.0	1897.4	278	5.1	10.0	16.2	35.7	11.0	814.3	71.0		
26	6724	6708.0	2044.6	283	5.1	10.0	15.9	36.5	6.7	800.0	55.0		
27	7000	6984.0	2128.7	285	4.8	9.3	15.6	36.9	4.5	792.5	48.0		
28	7481	7465.0	2275.3	289	4.1	8.0	15.0	37.5	0.6	778.9	37.0		
29	8000	7984.0	2433.5	289	3.6	7.0	14.3	38.3	-0.5	764.5	36.0		
30	8516	8500.0	2590.8	291	2.6	5.0	13.9	39.4	-3.2	750.0	30.0		
31	8717	8701.0	2652.1	292	2.6	5.0	13.8	39.9	-4.3	745.0	28.0		
32	9000	8984.0	2738.3	302	1.7	3.3	13.1	40.0	-4.8	737.4	28.0		
33	9266	9250.0	2819.4	319	1.5	2.9	12.7	40.5	-5.0	730.3	29.7		**
34	9798	9782.0	2981.6	354	1.0	2.0	11.9	41.3	-5.5	716.4	29.0	*	

* - INDICATES THE CALCULATED TOP OF THE SURFACE MIXING LAYER

** - INDICATES THAT DATA IS LINEARLY INTERPOLATED FROM INPUT METEOROLOGY

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1*****************************************************************************
             ROCKET EXHAUST EFFLUENT DIFFUSION MODEL REEDM        PAGE    4
                         VERSION 7.07 AT CCAS
                          1536 EDT  9 SEP 1996
                 launch time:  2030 EDT 02 JUL 1996
     RAWINSONDE ASCENT NUMBER      0, 2345   Z  2 JUL   96  T  -0.8 HR
*****************************************************************************

               ----- METEOROLOGICAL RAWINSONDE DATA -----


  SURFACE AIR DENSITY (GM/M**3)                                        1153.82
  DEFAULT CALCULATED MIXING LAYER HEIGHT (M)                           2981.55
  CLOUD COVER IN TENTHS OF CELESTIAL DOME                                  0.0
  CLOUD CEILING (M)                                                     9999.0
                    ----- PLUME RISE DATA -----

 EXHAUST RATE OF MATERIAL INTO GRN CLD-    (GRAMS/SEC)         4.25910E+06
 TOTAL GROUND CLD MATERIAL-                (GRAMS)             4.00875E+07
 HEAT OUTPUT PER GRAM-                     (CALORIES)               1555.6
 VEHICLE RISE HEIGHT DEFINING GROUND CLD-  (M)                       199.9
 VEHICLE RISE TIME PARAMETERS-             (TK=(A*Z**B)+C)  A=      0.8677
                                                            B=      0.4500
                                                            C=      0.0000
 EXHAUST RATE OF MATERIAL INTO CONTRAIL-   (GRAMS/SEC)         4.25910E+06
 CONTRAIL HEAT OUTPUT PER GRAM-            (CALORIES)               1555.6
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launch time: 2030 EDT 02 JUL 1996
RAWINSONDE ASCENT NUMBER 0, 2345 Z 2 JUL 96 T -0.8 HR
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----- EXHAUST CLOUD -----

MET. LAYER NO.	TOP OF LAYER (METERS)	CLOUD RISE TIME (SECONDS)	CLOUD RISE RANGE (METERS)	CLOUD RISE BEARING (DEGREES)	STABILIZED CLOUD RANGE (METERS)	STABILIZED CLOUD BEARING (DEGREES)
1	15.2	2.7	3.7	1.7	0.0	0.0
2	30.5	4.3	10.8	4.1	0.0	0.0
3	45.7	5.8	17.2	6.8	0.0	0.0
4	61.0	7.4	24.6	9.8	0.0	0.0
5	79.4	9.4	34.3	13.2	0.0	0.0
6	97.8	11.5	45.9	16.1	0.0	0.0
7	126.1	15.1	61.9	19.1	0.0	0.0
8	154.3	19.1	83.7	22.3	0.0	0.0
9	182.6	23.6	108.6	25.4	0.0	0.0
10	241.2	34.2	153.9	29.8	0.0	0.0
11	299.9	46.5	223.6	33.6	0.0	0.0
12	427.6	78.9	360.0	37.8	3418.7	44.9
13	555.3	120.3	585.6	41.6	3387.5	47.9
14	604.7	139.3	770.9	43.7	3498.8	49.8
15	757.1	210.4	1054.0	46.1	3344.8	51.2
16	909.5	307.4	1572.2	49.1	3209.5	52.9
17	1031.1	426.0	2216.4	51.7	3082.6	54.1
18	1128.7	574.9 *	3386.8	55.4	3386.8	55.4
19	1214.3	574.9 *	3386.8	55.4	3386.8	55.4
20	1323.7	574.9 *	3386.8	55.4	3386.8	55.4
21	1519.1	574.9 *	3386.8	55.4	3386.8	55.4
22	1671.5	574.9 *	3386.8	55.4	3386.8	55.4
23	1823.9	574.9 *	3386.8	55.4	3386.8	55.4
24	1897.4	574.9 *	3386.8	55.4	3386.8	55.4
25	2044.6	574.9 *	3386.8	55.4	3386.8	55.4
26	2128.7	574.9 *	3386.8	55.4	3386.8	55.4
27	2275.3	574.9 *	3386.8	55.4	3386.8	55.4
28	2433.5	574.9 *	3386.8	55.4	3386.8	55.4
29	2590.8	574.9 *	3386.8	55.4	3386.8	55.4
30	2652.1	574.9 *	3386.8	55.4	3386.8	55.4
31	2738.3	574.9 *	3386.8	55.4	3386.8	55.4
32	2819.4	574.9 *	3386.8	55.4	3386.8	55.4
33	2981.6	574.9 *	3386.8	55.4	3386.8	55.4

* - INDICATES CLOUD STABILIZATION TIME WAS USED

----- EXHAUST CLOUD -----

CHEMICAL SPECIES = HCL

MET. LAYER NO.	TOP OF LAYER (METERS)	LAYER SOURCE STRENGTH (GRAMS)	CLOUD UPDRAFT VELOCITY (M/S)	CLOUD RADIUS (METERS)	STD. DEVIATION MATERIAL DIST. ALONGWIND (METERS)	CROSSWIND (METERS)
1	15.2	0.00000E+00	8.9	0.0	0.0	0.0
2	30.5	0.00000E+00	10.0	0.0	0.0	0.0
3	45.7	0.00000E+00	10.0	0.0	0.0	0.0
4	61.0	0.00000E+00	9.6	0.0	0.0	0.0
5	79.4	0.00000E+00	8.9	0.0	0.0	0.0
6	97.8	0.00000E+00	8.3	0.0	0.0	0.0
7	126.1	0.00000E+00	7.4	0.0	0.0	0.0
8	154.3	0.00000E+00	6.7	0.0	0.0	0.0
9	182.6	0.00000E+00	6.0	0.0	0.0	0.0
10	241.2	0.00000E+00	5.1	0.0	0.0	0.0
11	299.9	0.00000E+00	4.4	0.0	0.0	0.0
12	427.6	3.32132E+04	3.5	220.1	102.6	102.6
13	555.3	6.16760E+05	2.7	395.7	184.4	184.4
14	604.7	4.23549E+05	2.5	524.8	244.5	244.5
15	757.1	1.82990E+06	1.8	622.5	290.1	290.1
16	909.5	2.41118E+06	1.3	714.0	332.7	332.7
17	1031.1	2.16128E+06	0.7	756.0	352.3	352.3
18	1128.7 *	2.07718E+06	0.0	766.8	357.3	357.3
19	1214.3 *	2.12280E+06	0.0	761.1	354.7	354.7
20	1323.7 *	2.57044E+06	0.0	740.0	344.8	344.8
21	1519.1 *	3.91290E+06	0.0	672.0	313.1	313.1
22	1671.5 *	2.15352E+06	0.0	522.4	243.4	243.4
23	1823.9 *	1.12785E+06	0.0	236.2	110.1	110.1
24	1897.4 *	3.84324E+05	0.0	199.9	93.2	93.2
25	2044.6 *	7.46325E+05	0.0	199.9	93.2	93.2
26	2128.7 *	4.13243E+05	0.0	199.9	93.2	93.2
27	2275.3 *	6.99246E+05	0.0	199.9	93.2	93.2
28	2433.5 *	7.27223E+05	0.0	199.9	93.2	93.2
29	2590.8 *	6.97671E+05	0.0	199.9	93.2	93.2
30	2652.1 *	2.65445E+05	0.0	199.9	93.2	93.2
31	2738.3 *	3.68080E+05	0.0	199.9	93.2	93.2
32	2819.4 *	3.40199E+05	0.0	199.9	93.2	93.2
33	2981.6 *	6.64608E+05	0.0	199.9	93.2	93.2

* - INDICATES CLOUD STABILIZATION TIME WAS USED

----- CLOUD STABILIZATION -----

CALCULATION HEIGHT	(METERS)	1086.68
STABILIZATION HEIGHT	(METERS)	1086.68
STABILIZATION TIME	(SECS)	574.86
FIRST MIXING LAYER HEIGHT-	(METERS)	TOP = 2981.55
		BASE= 0.00
SIGMAR(AZ) AT THE SURFACE	(DEGREES)	7.9724
SIGMER(EL) AT THE SURFACE	(DEGREES)	4.9445

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
1	3.10	0.77	182.75	5.50	6.2980	4.3550
2	3.73	0.77	188.25	5.50	4.3244	3.6394
3	4.50	0.77	193.75	5.50	3.8684	3.4436
4	5.27	0.77	199.25	5.50	3.6079	3.3259
5	5.66	0.00	203.25	2.50	3.4139	3.2353
6	5.66	0.00	205.75	2.50	3.2557	3.1596
7	5.74	0.17	209.17	4.33	3.1656	3.1084
8	5.92	0.17	213.50	4.33	3.1327	3.0798
9	6.09	0.17	217.83	4.33	3.1056	3.0534
10	6.17	0.00	221.00	2.00	3.0669	3.0159
11	6.17	0.00	223.00	2.00	3.0094	2.9600
12	6.17	0.00	225.75	3.50	2.9257	2.8788
13	6.17	0.00	229.25	3.50	2.8438	2.7992
14	6.28	0.21	231.50	1.00	2.7721	2.7295
15	6.30	-0.15	233.50	3.00	2.6762	2.6364
16	6.15	0.15	236.50	3.00	2.5666	2.5299
17	5.86	0.41	240.00	4.00	2.4732	2.4392
18	5.66	0.00	243.50	3.00	2.3970	2.3652
19	5.66	0.00	246.50	3.00	2.3254	2.2957
20	5.66	0.00	249.50	3.00	2.2308	2.2037
21	5.53	-0.26	256.00	10.00	2.1072	2.0837
22	5.35	-0.10	264.50	7.00	1.9836	1.9637
23	5.25	-0.10	271.50	7.00	1.8832	1.8661
24	5.17	-0.05	276.50	3.00	1.7986	1.7840
25	5.14	0.00	280.50	5.00	1.7130	1.7009
26	4.96	-0.36	284.00	2.00	1.6255	1.6159
27	4.45	-0.67	287.00	4.00	1.5241	1.5174
28	3.86	-0.51	289.00	0.00	1.4067	1.4033
29	3.09	-1.03	290.00	2.00	1.3059	1.3051
30	2.57	0.00	291.50	1.00	1.2378	1.2378

----- CALCULATED METEOROLOGICAL LAYER PARAMETERS -----

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
31	2.13	-0.87	297.00	10.00	1.1799	1.1799
32	1.59	-0.22	310.67	17.33	1.1044	1.1044
33	1.25	-0.45	336.67	34.67	1.0596	1.0596

ALTITUDE RANGE USED IN COMPUTING TRANSITION LAYER AVERAGES
IS 1.0 TO 2981.6 METERS.

TRANSITION LAYER NUMBER- 1

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	2981.55	314.46	1.03		354.00		1.0596	1.0596
LAYER-			4.33	1.21	252.80	18.65	2.1062	2.0665
BOTTOM-	0.00	304.31	2.57		180.00		7.9724	4.9445

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ROCKET EXHAUST EFFLUENT DIFFUSION MODEL REEDM PAGE 9
VERSION 7.07 AT CCAS
1536 EDT 9 SEP 1996
launch time: 2030 EDT 02 JUL 1996
RAWINSONDE ASCENT NUMBER 0, 2345 Z 2 JUL 96 T -0.8 HR

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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 1086.7 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	PEAK CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
4000.1211	58.0487	19.2966	5.6611	15.0242
5000.0576	61.0302	16.7088	7.9295	19.0062
6000.0156	63.0793	13.9197	10.4966	22.9943
7000.0073	64.4312	11.6409	14.2400	26.9921
8000.0039	65.4350	9.7460	17.9400	31.0076
9000.0020	66.2140	8.1580	21.6069	35.0412
10000.0010	66.8363	6.8225	25.2482	39.0916
11000.0010	67.3448	5.7024	28.8696	43.1569
12000.0010	67.7683	4.7699	32.4756	47.2354
13000.0000	68.1264	3.9994	36.0693	51.3252
14000.0000	68.4331	3.3661	39.6532	55.4247
15000.0000	68.6989	2.8468	43.2293	59.5325
16000.0000	68.9313	2.4210	46.7990	63.6475
17000.0000	69.1364	2.0711	50.3634	67.7686
18000.0000	69.3186	1.7829	53.9234	71.8950
19000.0000	69.4816	1.5445	57.4797	76.0259
20000.0000	69.6283	1.3464	61.0281	80.1608
21000.0000	69.7610	1.1811	64.5628	84.2991
22000.0000	70.2196	1.0417	68.1187	88.4661
23000.0000	70.3317	0.9250	71.6523	92.6103
24000.0000	70.4346	0.8261	75.1853	96.7568
25000.0000	70.5292	0.7419	78.7178	100.9054
26000.0000	70.6165	0.6697	82.2499	105.0558
27000.0000	70.6973	0.6076	85.7816	109.2078
28000.0000	70.7724	0.5537	89.3130	113.3612
29000.0000	70.8422	0.5069	92.8441	117.5159
30000.0000	70.9075	0.4659	96.3749	121.6718
31000.0000	70.9685	0.4298	99.9055	125.8288
32000.0000	71.0257	0.3979	103.4359	129.9867
33000.0000	71.0794	0.3696	106.9660	134.1454
34000.0000	71.1300	0.3443	110.4960	138.3050
35000.0000	71.1776	0.3217	114.0259	142.4653
36000.0000	71.2227	0.3013	117.5555	146.6262
37000.0000	71.2653	0.2829	121.0851	150.7877
38000.0000	71.3056	0.2662	124.6145	154.9498

launch time: 2030 EDT 02 JUL 1996
RAWINSONDE ASCENT NUMBER 0, 2345 Z 2 JUL 96 T -0.8 HR
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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 1086.7 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	PEAK CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
39000.0000	71.3439	0.2510	128.1438	159.1124
40000.0000	71.3802	0.2371	131.6730	163.2755
41000.0000	71.4148	0.2244	135.2021	167.4390
42000.0000	71.4478	0.2128	138.7311	171.6029
43000.0000	71.4792	0.2020	142.2600	175.7672
44000.0000	71.5092	0.1921	145.7889	179.9318
45000.0000	71.5378	0.1829	149.3176	184.0968
46000.0000	71.5652	0.1744	152.8463	188.2621
47000.0000	71.5914	0.1664	156.3750	192.4276
48000.0000	71.6166	0.1591	159.9035	196.5934
49000.0000	71.6407	0.1522	163.4321	200.7595
50000.0000	71.6639	0.1457	166.9605	204.9258
51000.0000	71.6861	0.1397	170.4890	209.0923
52000.0000	71.7075	0.1340	174.0174	213.2590
53000.0000	71.7281	0.1286	177.5457	217.4259
54000.0000	71.7479	0.1236	181.0740	221.5930
55000.0000	71.7670	0.1189	184.6022	225.7603
56000.0000	71.7854	0.1145	188.1304	229.9277
57000.0000	71.8032	0.1102	191.6586	234.0953
58000.0000	71.8203	0.1063	195.1868	238.2630
59000.0000	71.8369	0.1025	198.7149	242.4309
60000.0000	71.8529	0.0989	202.2430	246.5989

	RANGE	BEARING
19.297 IS THE MAXIMUM PEAK CONCENTRATION	4000.1	58.0

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 1086.7 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	60.0 MIN. MEAN CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
4000.1211	58.0487	1.1107	5.6611	15.0242
5000.0576	61.0302	0.9721	7.9295	19.0062
6000.0156	63.0793	0.8261	10.4966	22.9943
7000.0073	64.4312	0.7101	14.2400	26.9921
8000.0039	65.4350	0.6153	17.9400	31.0076
9000.0020	66.2140	0.5364	21.6069	35.0412
10000.0010	66.8363	0.4696	25.2482	39.0916
11000.0010	67.3448	0.4127	28.8696	43.1569
12000.0010	67.7683	0.3640	32.4756	47.2354
13000.0000	68.1264	0.3223	36.0693	51.3252
14000.0000	68.4331	0.2867	39.6532	55.4247
15000.0000	68.6989	0.2562	43.2293	59.5325
16000.0000	68.9313	0.2300	46.7990	63.6475
17000.0000	69.1364	0.2074	50.3634	67.7686
18000.0000	69.3186	0.1880	53.9234	71.8950
19000.0000	69.4816	0.1712	57.4797	76.0259
20000.0000	69.6283	0.1567	61.0281	80.1608
21000.0000	69.7610	0.1440	64.5628	84.2991
22000.0000	70.2196	0.1330	68.1187	88.4661
23000.0000	70.3317	0.1234	71.6523	92.6103
24000.0000	70.4346	0.1150	75.1853	96.7568
25000.0000	70.5292	0.1075	78.7178	100.9054
26000.0000	70.6165	0.1010	82.2499	105.0558
27000.0000	70.6973	0.0952	85.7816	109.2078
28000.0000	70.7724	0.0901	89.3130	113.3612
29000.0000	70.8422	0.0855	92.8441	117.5159
30000.0000	70.9075	0.0813	96.3749	121.6718
31000.0000	70.9685	0.0776	99.9055	125.8288
32000.0000	71.0257	0.0742	103.4359	129.9867
33000.0000	71.0794	0.0712	106.9660	134.1454
34000.0000	71.1300	0.0684	110.4960	138.3050
35000.0000	71.1776	0.0659	114.0259	142.4653
36000.0000	71.2227	0.0635	117.5555	146.6262
37000.0000	71.2653	0.0614	121.0851	150.7877

VERSION 7.07 AT CCAS
1536 EDT 9 SEP 1996
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RAWINSONDE ASCENT NUMBER 0, 2345 Z 2 JUL 96 T -0.8 HR
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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 1086.7 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	60.0 MIN. MEAN CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
38000.0000	71.3056	0.0594	124.6145	154.9498
39000.0000	71.3439	0.0575	128.1438	159.1124
40000.0000	71.3802	0.0558	131.6730	163.2755
41000.0000	71.4148	0.0542	135.2021	167.4390
42000.0000	71.4478	0.0527	138.7311	171.6029
43000.0000	71.4792	0.0512	142.2600	175.7672
44000.0000	71.5092	0.0499	145.7889	179.9318
45000.0000	71.5378	0.0486	149.3176	184.0968
46000.0000	71.5652	0.0474	152.8463	188.2621
47000.0000	71.5914	0.0463	156.3750	192.4276
48000.0000	71.6166	0.0452	159.9035	196.5934
49000.0000	71.6407	0.0442	163.4321	200.7595
50000.0000	71.6639	0.0432	166.9605	204.9258
51000.0000	71.6861	0.0423	170.4890	209.0923
52000.0000	71.7075	0.0414	174.0174	213.2590
53000.0000	71.7281	0.0406	177.5457	217.4259
54000.0000	71.7479	0.0397	181.0740	221.5930
55000.0000	71.7670	0.0390	184.6022	225.7603
56000.0000	71.7854	0.0382	188.1304	229.9277
57000.0000	71.8032	0.0375	191.6586	234.0953
58000.0000	71.8203	0.0368	195.1868	238.2630
59000.0000	71.8369	0.0361	198.7149	242.4309
60000.0000	71.8529	0.0355	202.2430	246.5989

	RANGE	BEARING
1.111 IS THE MAXIMUM 60.0 MIN. MEAN CONCENTRATION	4000.1	58.0

*** REEDM HAS TERMINATED

Surface Impact Predictions

This section includes the REEDM version 7.07 output for the surface impact run. For this run, we included the plots of the rawinsonde meteorological data, the predicted maximum concentration versus downwind distance, and the predicted concentration isopleths overlayed on a range map. The rawinsonde meteorological data is identical to the data plotted in Figure A1 for the stabilization height run. Lastly, this section includes the detailed REEDM report for this run. The first page of the REEDM output is its listing of errors and is not included in this appendix.

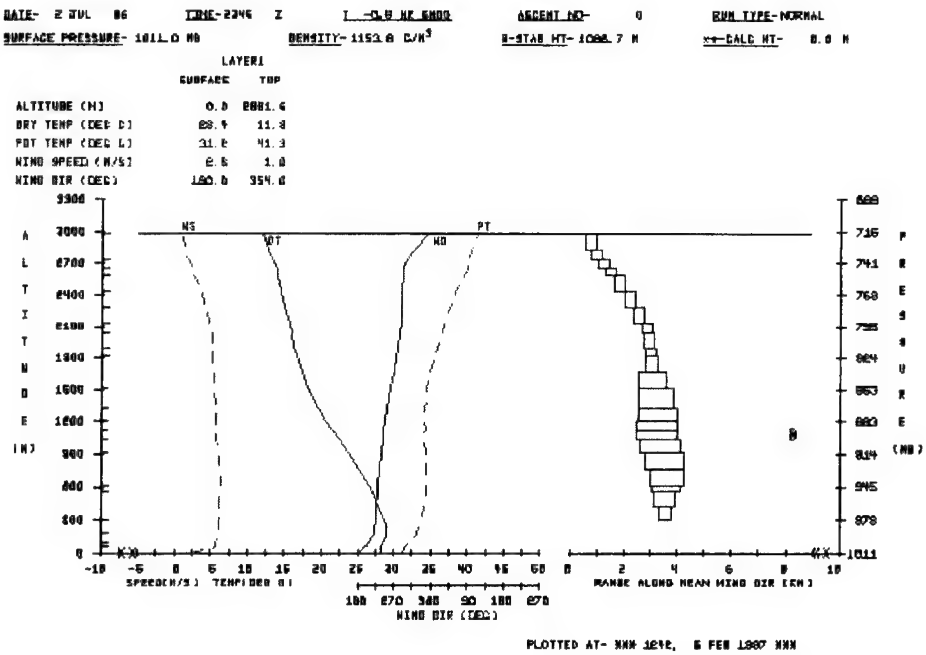

Figure A4. Meteorological output plot from REEDM Version 7.07 for #K2 mission using T-0.8h rawinsonde data.

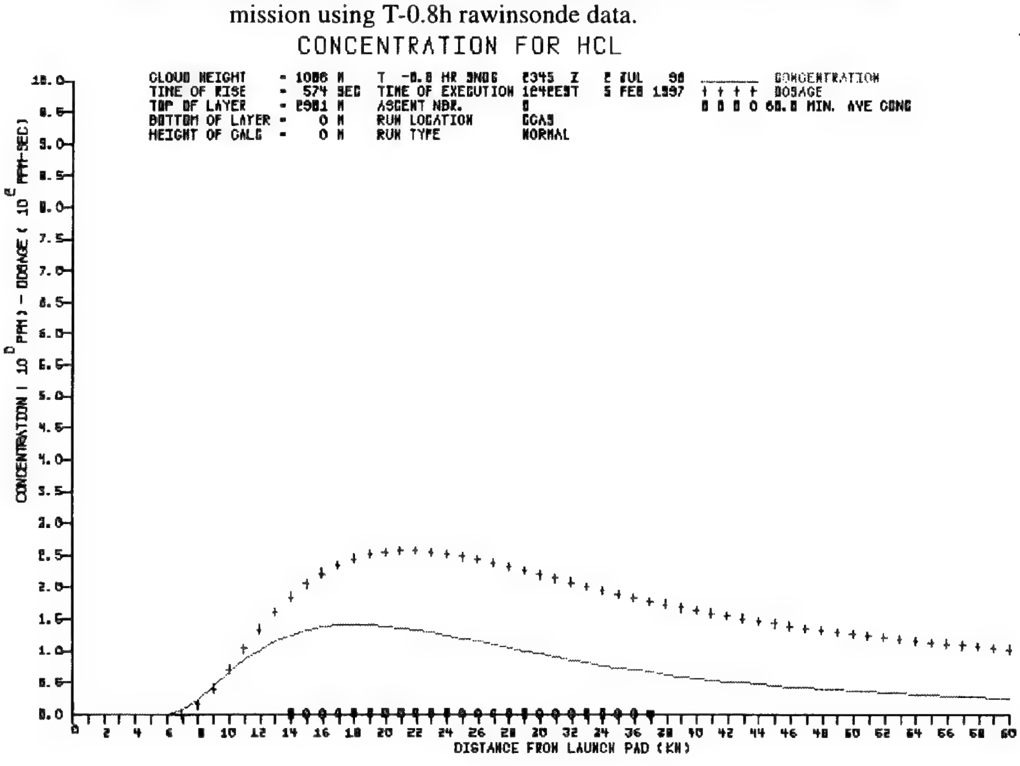

Figure A5. HCl surface height concentration predictions from REEDM Version 7.07 for #K2 mission using T-0.8h rawinsonde data.

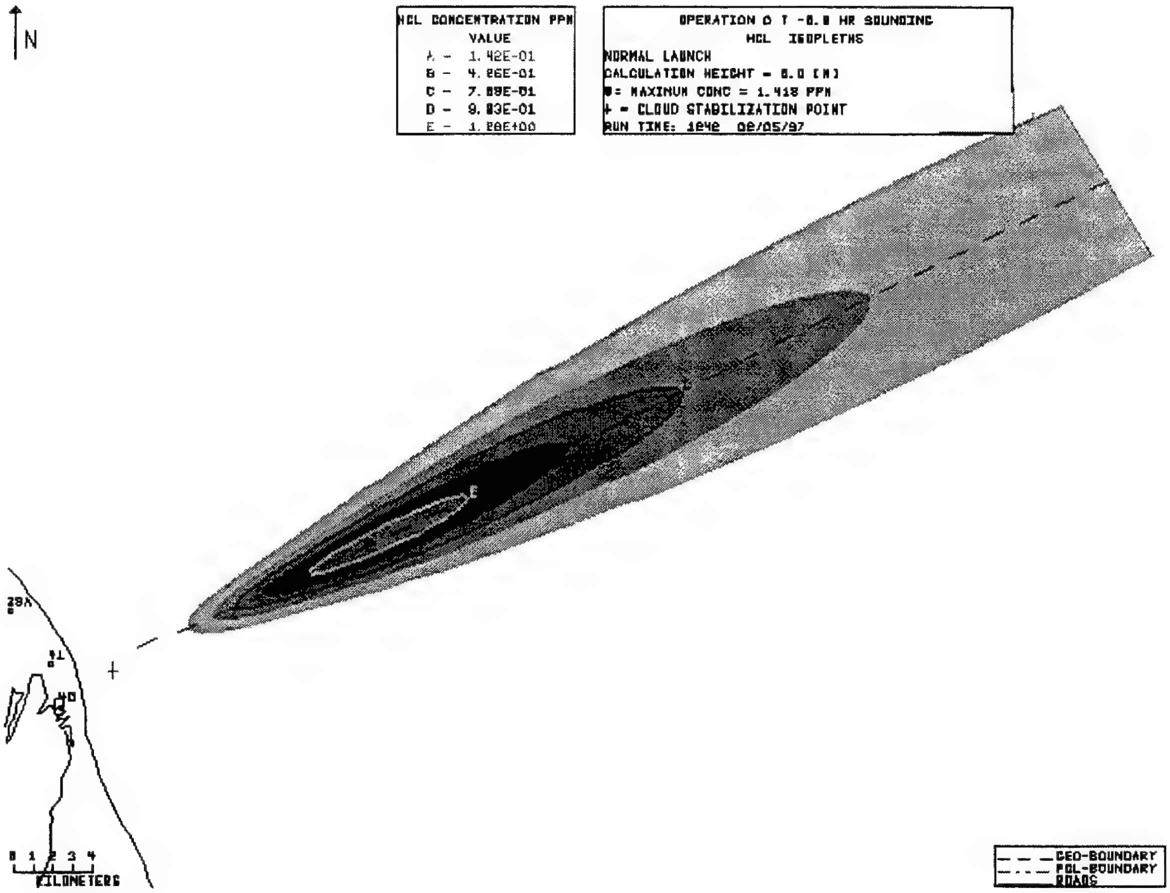

Figure A6. HCl surface height concentration isopleth predictions from REEDM Version 7.07 for #K2 mission using T-0.8h rawinsonde data.

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                       ----- PROGRAM OPTIONS -----

 MODEL                                                      CONCENTRATION
 RUN TYPE                                                     OPERATIONAL
 WIND-FIELD TERRAIN EFFECTS MODEL                                    NONE
 LAUNCH VEHICLE                                                  TITAN IV
 LAUNCH TYPE                                                       NORMAL
 LAUNCH COMPLEX NUMBER                                                 40
 TURBULENCE PARAMETERS ARE DETERMINED FROM             CLIMATOLOGICAL DATA
 SURFACE CHEMISTRY MODEL                           absorption coefficient
 SPECIES      SURFACE FACTOR                           HCL          0.000
 CLOUD SHAPE                                                   ELLIPTICAL
 CALCULATION HEIGHT                                               SURFACE
 PROPELLANT TEMPERATURE (DEG. C)                                    28.38

                         ----- DATA FILES -----

                              INPUT FILES
 RAWINSONDE FILE                                                   RAWIND
 DATA BASE FILE                                                   RDMBASE

                              OUTPUT FILES
 PRINT FILE                                                    nl2345.184
 PLOT FILE                                                   grnl2345.184
```

----- METEOROLOGICAL RAWINSONDE DATA -----

RAWINSONDE MSS/MSS
TIME- 2345 Z DATE- 02 JUL 96
ASCENT NUMBER 0

----- T -0.8 HR SOUNDING -----

MET. LEV. NO.	ALTITUDE MSL (FT)	ALTITUDE GND (FT)	GND (M)	WIND DIR (DEG)	WIND SPEED (M/S)	WIND SPEED (KTS)	TEMP (DEG C)	AIR PTEMP (DEG C)	DPTEMP (DEG C)	AIR PRESS (MB)	AIR RH (%)	H M	INT-ERP
1	16	0.0	0.0	180	2.6	5.0	28.4	31.2	25.4	1011.0	84.0		
2	66	50.0	15.2	186	3.3	6.5	28.4	31.3	25.4	1009.3	83.8		**
3	116	100.0	30.5	191	4.1	8.0	28.4	31.4	25.4	1007.5	83.8		**
4	166	150.0	45.7	197	4.9	9.5	28.3	31.5	25.3	1005.8	83.8		**
5	216	200.0	61.0	202	5.7	11.0	28.3	31.7	25.3	1004.1	84.0		
6	276	260.5	79.4	205	5.7	11.0	28.4	31.9	25.0	1002.0	81.6		**
7	337	321.0	97.8	207	5.7	11.0	28.5	32.1	24.6	1000.0	79.0		
8	430	413.7	126.1	211	5.8	11.3	28.7	32.4	24.0	996.9	75.8		**
9	522	506.3	154.3	216	6.0	11.7	28.9	32.8	23.4	993.7	72.3		**
10	615	599.0	182.6	220	6.2	12.0	29.1	33.2	22.8	990.6	69.0		
11	808	791.5	241.2	222	6.2	12.0	28.9	33.5	22.2	984.1	67.2		**
12	1000	984.0	299.9	224	6.2	12.0	28.7	33.8	21.6	977.7	66.0		
13	1419	1403.0	427.6	228	6.2	12.0	27.9	34.0	20.7	963.7	65.3		**
14	1838	1822.0	555.3	231	6.2	12.0	27.0	34.3	19.8	950.0	65.0		
15	2000	1984.0	604.7	232	6.4	12.4	26.6	34.3	19.6	944.8	65.0		
16	2500	2484.0	757.1	235	6.2	12.1	25.1	34.3	19.0	928.6	68.7		**
17	3000	2984.0	909.5	238	6.1	11.8	23.7	34.3	18.3	912.8	72.0		
18	3399	3383.0	1031.1	242	5.7	11.0	22.4	34.2	18.0	900.0	76.0		
19	3719	3703.0	1128.7	245	5.7	11.0	21.5	34.2	17.9	890.2	80.0		
20	4000	3984.0	1214.3	248	5.7	11.0	20.6	34.2	17.9	881.5	84.0		
21	4359	4343.0	1323.7	251	5.7	11.0	19.5	34.2	17.8	870.4	90.0		
22	5000	4984.0	1519.1	261	5.4	10.5	18.1	34.4	15.9	851.0	87.0		
23	5500	5484.0	1671.5	268	5.3	10.3	17.4	34.9	13.7	836.0	79.5		**
24	6000	5984.0	1823.9	275	5.2	10.1	16.6	35.4	11.5	821.3	72.0		
25	6241	6225.0	1897.4	278	5.1	10.0	16.2	35.7	11.0	814.3	71.0		
26	6724	6708.0	2044.6	283	5.1	10.0	15.9	36.5	6.7	800.0	55.0		
27	7000	6984.0	2128.7	285	4.8	9.3	15.6	36.9	4.5	792.5	48.0		
28	7481	7465.0	2275.3	289	4.1	8.0	15.0	37.5	0.6	778.9	37.0		
29	8000	7984.0	2433.5	289	3.6	7.0	14.3	38.3	-0.5	764.5	36.0		
30	8516	8500.0	2590.8	291	2.6	5.0	13.9	39.4	-3.2	750.0	30.0		
31	8717	8701.0	2652.1	292	2.6	5.0	13.8	39.9	-4.3	745.0	28.0		
32	9000	8984.0	2738.3	302	1.7	3.3	13.1	40.0	-4.8	737.4	28.0		
33	9266	9250.0	2819.4	319	1.5	2.9	12.7	40.5	-5.0	730.3	29.7		**
34	9798	9782.0	2981.6	354	1.0	2.0	11.9	41.3	-5.5	716.4	29.0	*	

* - INDICATES THE CALCULATED TOP OF THE SURFACE MIXING LAYER
** - INDICATES THAT DATA IS LINEARLY INTERPOLATED FROM INPUT METEOROLOGY

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                ----- METEOROLOGICAL RAWINSONDE DATA -----


  SURFACE AIR DENSITY (GM/M**3)                                   1153.82
  DEFAULT CALCULATED MIXING LAYER HEIGHT (M)                      2981.55
  CLOUD COVER IN TENTHS OF CELESTIAL DOME                             0.0
  CLOUD CEILING (M)                                                9999.0
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1***

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RAWINSONDE ASCENT NUMBER 0, 2345 Z 2 JUL 96 T -0.8 HR

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----- EXHAUST CLOUD -----

MET. LAYER NO.	TOP OF LAYER (METERS)	CLOUD RISE TIME (SECONDS)	CLOUD RISE RANGE (METERS)	CLOUD RISE BEARING (DEGREES)	STABILIZED CLOUD RANGE (METERS)	STABILIZED CLOUD BEARING (DEGREES)
1	15.2	2.7	3.7	1.7	0.0	0.0
2	30.5	4.3	10.8	4.1	0.0	0.0
3	45.7	5.8	17.2	6.8	0.0	0.0
4	61.0	7.4	24.6	9.8	0.0	0.0
5	79.4	9.4	34.3	13.2	0.0	0.0
6	97.8	11.5	45.9	16.1	0.0	0.0
7	126.1	15.1	61.9	19.1	0.0	0.0
8	154.3	19.1	83.7	22.3	0.0	0.0
9	182.6	23.6	108.6	25.4	0.0	0.0
10	241.2	34.2	153.9	29.8	0.0	0.0
11	299.9	46.5	223.6	33.6	0.0	0.0
12	427.6	78.9	360.0	37.8	3418.7	44.9
13	555.3	120.3	585.6	41.6	3387.5	47.9
14	604.7	139.3	770.9	43.7	3498.8	49.8
15	757.1	210.4	1054.0	46.1	3344.8	51.2
16	909.5	307.4	1572.2	49.1	3209.5	52.9
17	1031.1	426.0	2216.4	51.7	3082.6	54.1
18	1128.7	574.9 *	3386.8	55.4	3386.8	55.4
19	1214.3	574.9 *	3386.8	55.4	3386.8	55.4
20	1323.7	574.9 *	3386.8	55.4	3386.8	55.4
21	1519.1	574.9 *	3386.8	55.4	3386.8	55.4
22	1671.5	574.9 *	3386.8	55.4	3386.8	55.4
23	1823.9	574.9 *	3386.8	55.4	3386.8	55.4
24	1897.4	574.9 *	3386.8	55.4	3386.8	55.4
25	2044.6	574.9 *	3386.8	55.4	3386.8	55.4
26	2128.7	574.9 *	3386.8	55.4	3386.8	55.4
27	2275.3	574.9 *	3386.8	55.4	3386.8	55.4
28	2433.5	574.9 *	3386.8	55.4	3386.8	55.4
29	2590.8	574.9 *	3386.8	55.4	3386.8	55.4
30	2652.1	574.9 *	3386.8	55.4	3386.8	55.4
31	2738.3	574.9 *	3386.8	55.4	3386.8	55.4
32	2819.4	574.9 *	3386.8	55.4	3386.8	55.4
33	2981.6	574.9 *	3386.8	55.4	3386.8	55.4

* - INDICATES CLOUD STABILIZATION TIME WAS USED

----- CLOUD STABILIZATION -----

CALCULATION HEIGHT	(METERS)	0.00
STABILIZATION HEIGHT	(METERS)	1086.68
STABILIZATION TIME	(SECS)	574.86
FIRST MIXING LAYER HEIGHT-	(METERS)	TOP = 2981.55
		BASE= 0.00
SIGMAR(AZ) AT THE SURFACE	(DEGREES)	7.9724
SIGMER(EL) AT THE SURFACE	(DEGREES)	4.9445

1***

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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	PEAK CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
6000.0591	53.0865	0.0080	8.4769	15.9473
7000.0620	55.1231	0.0696	11.6474	23.1506
8000.0005	56.7605	0.2234	14.7864	26.3330
9000.0010	57.7321	0.4384	17.9024	29.5022
10000.0000	58.5117	0.6625	21.0054	32.6679
11000.0000	59.2007	0.8626	24.1016	35.8359
12000.0000	59.6239	1.0268	27.1826	38.9970
13000.0000	60.0325	1.1560	30.2597	42.1623
14000.0000	60.4297	1.2550	33.3328	45.3312
15000.0000	60.8180	1.3276	36.4020	48.5032
16000.0000	60.9208	1.3768	39.4575	51.6678
17000.0000	61.2927	1.4066	42.5199	54.8457
18000.0000	61.3760	1.4183	45.5695	58.0162
19000.0000	61.4506	1.4141	48.6164	61.1892
20000.0000	61.8063	1.3973	51.6692	64.3746
21000.0000	61.8690	1.3704	54.6909	67.5525
22000.0000	61.9259	1.3350	57.7119	70.7326
23000.0000	61.9779	1.2932	60.7322	73.9147
24000.0000	62.0256	1.2469	63.7520	77.0988
25000.0000	62.0694	1.1978	66.7713	80.2846
26000.0000	62.1099	1.1471	69.7902	83.4721
27000.0000	62.1474	1.0959	72.8086	86.6612
28000.0000	62.1822	1.0450	75.8268	89.8519
29000.0000	62.2146	0.9950	78.8446	93.0439
30000.0000	62.2448	0.9463	81.8622	96.2372
31000.0000	62.5767	0.8994	84.8884	99.4411
32000.0000	62.6041	0.8545	87.9055	102.6369
33000.0000	62.6298	0.8117	90.9225	105.8338
34000.0000	62.6540	0.7710	93.9393	109.0317
35000.0000	62.6768	0.7324	96.9559	112.2306
36000.0000	62.6983	0.6960	99.9724	115.4303
37000.0000	62.7187	0.6616	102.9887	118.6309
38000.0000	62.7380	0.6292	106.0049	121.8323
39000.0000	62.7563	0.5988	109.0210	125.0345
40000.0000	62.7737	0.5703	112.0370	128.2374

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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	PEAK CONCEN- TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
41000.0000	62.7903	0.5435	115.0529	131.4409
42000.0000	62.8061	0.5183	118.0687	134.6451
43000.0000	62.8211	0.4947	121.0844	137.8499
44000.0000	62.8354	0.4726	124.1000	141.0552
45000.0000	62.8491	0.4518	127.1156	144.2611
46000.0000	62.8622	0.4323	130.1311	147.4675
47000.0000	62.8748	0.4139	133.1465	150.6743
48000.0000	62.8868	0.3967	136.1619	153.8817
49000.0000	62.8984	0.3805	139.1772	157.0894
50000.0000	62.9095	0.3652	142.1924	160.2976
51000.0000	62.9201	0.3508	145.2076	163.5061
52000.0000	62.9303	0.3373	148.2228	166.7150
53000.0000	62.9402	0.3245	151.2379	169.9243
54000.0000	62.9497	0.3124	154.2530	173.1339
55000.0000	62.9588	0.3010	157.2680	176.3438
56000.0000	62.9676	0.2902	160.2830	179.5540
57000.0000	62.9761	0.2800	163.2980	182.7645
58000.0000	62.9843	0.2703	166.3129	185.9753
59000.0000	62.9923	0.2611	169.3278	189.1864
60000.0000	62.9999	0.2523	172.3427	192.3977

	RANGE	BEARING
1.418 IS THE MAXIMUM PEAK CONCENTRATION	18000.0	61.4

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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	60.0 MIN. MEAN CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
7000.0005	55.3444	0.0014	11.6474	23.1506
8000.0005	56.7605	0.0056	14.7864	26.3330
9000.0664	57.9771	0.0126	17.9024	29.5022
10000.0869	58.7584	0.0212	21.0054	32.6679
11000.0000	59.2007	0.0301	24.1016	35.8359
12000.1201	59.8845	0.0386	27.1826	38.9970
13000.1367	60.2985	0.0462	30.2597	42.1623
14000.1533	60.7003	0.0528	33.3328	45.3312
15000.0000	60.8180	0.0585	36.4020	48.5032
16000.1865	61.1989	0.0631	39.4575	51.6678
17000.0000	61.2927	0.0667	42.5199	54.8457
18000.0000	61.3760	0.0694	45.5695	58.0162
19000.2363	61.7370	0.0713	48.6164	61.1892
20000.0000	61.8063	0.0724	51.6692	64.3746
21000.0000	61.8690	0.0729	54.6909	67.5525
22000.0000	61.9259	0.0728	57.7119	70.7326
23000.0000	61.9779	0.0723	60.7322	73.9147
24000.0000	62.0256	0.0714	63.7520	77.0988
25000.0000	62.0694	0.0703	66.7713	80.2846
26000.0000	62.1099	0.0690	69.7902	83.4721
27000.0000	62.1474	0.0675	72.8086	86.6612
28000.0000	62.1822	0.0659	75.8268	89.8519
29000.0000	62.2146	0.0642	78.8446	93.0439
30000.4180	62.5475	0.0625	81.8622	96.2372
31000.0000	62.5767	0.0608	84.8884	99.4411
32000.0000	62.6041	0.0591	87.9055	102.6369
33000.0000	62.6298	0.0574	90.9225	105.8338
34000.0000	62.6540	0.0558	93.9393	109.0317
35000.0000	62.6768	0.0542	96.9559	112.2306
36000.0000	62.6983	0.0526	99.9724	115.4303
37000.0000	62.7187	0.0511	102.9887	118.6309
38000.0000	62.7380	0.0497	106.0049	121.8323
39000.0000	62.7563	0.0483	109.0210	125.0345
40000.0000	62.7737	0.0470	112.0370	128.2374

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 2981.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	60.0 MIN. MEAN CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
41000.0000	62.7903	0.0457	115.0529	131.4409
42000.0000	62.8061	0.0445	118.0687	134.6451
43000.0000	62.8211	0.0433	121.0844	137.8499
44000.0000	62.8354	0.0422	124.1000	141.0552
45000.0000	62.8491	0.0412	127.1156	144.2611
46000.0000	62.8622	0.0401	130.1311	147.4675
47000.0000	62.8748	0.0392	133.1465	150.6743
48000.0000	62.8868	0.0383	136.1619	153.8817
49000.0000	62.8984	0.0374	139.1772	157.0894
50000.0000	62.9095	0.0366	142.1924	160.2976
51000.0000	62.9201	0.0358	145.2076	163.5061
52000.0000	62.9303	0.0350	148.2228	166.7150
53000.0000	62.9402	0.0343	151.2379	169.9243
54000.0000	62.9497	0.0336	154.2530	173.1339
55000.0000	62.9588	0.0329	157.2680	176.3438
56000.0000	62.9676	0.0323	160.2830	179.5540
57000.0000	62.9761	0.0317	163.2980	182.7645
58000.0000	62.9843	0.0311	166.3129	185.9753
59000.0000	62.9923	0.0305	169.3278	189.1864
60000.0000	62.9999	0.0300	172.3427	192.3977

	RANGE	BEARING
0.073 IS THE MAXIMUM 60.0 MIN. MEAN CONCENTRATION	21000.0	61.9

*** REEDM HAS TERMINATED

Appendix B—Meteorological Data for the #K2 Mission

[Tower data was provided by Randy Evans of ENSCO Inc. in the NASA Applied Meteorology Unit. Rawinsonde data was provided by R. N. Abernathy, The Aerospace Corp.]

The following data consist of rawinsonde data at T-1h and T-45 min, plus meteorological tower data at the time of launch, T + 10 min, and T + 20 min for the Titan IV #K2 launch on 3 July 1996.

Rawinsonde data is presented as formatted for input to the REEDM program. In this data, all wind directions are reported in the convention of rawinsonde wind vectors; the angle clockwise from true north from which the wind originates.

DAY	Year (1996) and day of year (115th)
TIME	ZULU (Greenwich Mean) time
LAT	Latitude
LON	Longitude
Z	Elevation abovbe ground level
DIR	Compass direction from which the wind originates
SPD	Wind speed in knots
T	Ambient temperature, °F
TD	Dew point temperature, °F
TIDN	Tower ID number

RS011842330
TEST NBR A4285 WS 6 3300
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
2330Z 02 JUL 96

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	180	6.0	.000	28.5	25.1	1011.00	82	22.87	1153.68	391	681	31.84	0
1000	218	12.8	.015	28.6	21.4	977.67	65	18.29	1117.68	356	680	25.47	6
2000	233	12.8	.006	26.5	19.6	944.79	66	16.49	1088.31	339	678	22.80	11
3000	239	11.8	.003	23.7	18.5	912.74	73	15.60	1061.71	329	675	21.37	16
4000	244	10.5	.003	20.1	17.9	881.45	87	15.12	1037.85	322	671	20.46	21
5000	256	10.0	.004	17.9	14.2	850.89	80	12.16	1011.23	299	667	16.33	25
6000	274	10.1	.005	16.9	8.7	821.18	59	8.49	981.32	270	666	11.37	28
7000	285	10.0	.003	15.5	2.4	792.36	41	5.47	952.89	246	663	7.29	30
8000	289	8.5	.003	14.3	-2.1	764.39	32	3.95	924.01	230	662	5.24	32
9000	290	5.8	.004	12.8	-5.0	737.27	28	3.18	896.19	219	660	4.20	33
10000	320	2.8	.006	11.0	-5.0	710.97	32	3.21	869.57	214	658	4.22	34
11000	27	2.9	.005	8.6	1.3	685.44	60	5.18	844.26	220	656	6.73	35
12000	53	3.4	.003	6.4	-2.6	660.63	53	3.99	820.84	208	653	5.14	36
13000	56	3.3	.000	4.9	-7.0	636.55	42	2.81	795.97	195	651	3.61	37
14000	55	2.5	.001	2.5	-7.7	613.17	47	2.69	773.31	189	648	3.42	38
15000	29	.5	.003	1.1	-11.3	590.51	39	2.06	748.78	180	646	2.61	39
16000	326	3.3	.005	-.1	-4.9	568.60	70	3.37	723.39	183	645	4.24	40
17000	315	5.8	.004	-1.2	-10.5	547.40	50	2.21	699.98	170	643	2.78	41
18000	306	8.5	.005	-3.0	-13.9	526.89	42	1.67	678.34	162	641	2.08	41
19000	295	10.4	.004	-4.4	-21.2	507.02	25	.91	656.62	152	639	1.13	42
20000	286	11.9	.004	-6.6	-21.6	487.77	29	.88	637.06	148	637	1.09	42
21000	284	12.2	.001	-8.6	-22.9	469.10	31	.79	617.37	143	634	.97	42
22000	289	10.8	.003	-10.7	-24.3	451.00	32	.70	598.32	138	632	.85	42
23000	301	8.0	.006	-12.1	-29.8	433.50	21	.43	578.18	132	630	.51	43
24000	304	6.6	.003	-13.9	-31.4	416.57	21	.37	559.63	127	628	.44	43
25000	301	5.9	.001	-16.3	-30.3	400.18	28	.41	542.44	124	625	.49	43
26000	307	6.0	.001	-18.2	-32.4	384.29	27	.34	524.96	119	622	.40	43
27000	314	7.2	.002	-20.3	-34.4	368.93	27	.28	508.06	115	620	.33	43
28000	321	8.6	.003	-22.7	-37.0	354.05	25	.22	492.32	111	617	.25	43
29000	324	10.3	.003	-25.0	-38.9	339.64	26	.18	476.81	107	614	.21	43
30000	323	13.1	.005	-27.5	-41.0	325.68	26	.15	461.84	104	611	.17	43
31000	322	14.6	.003	-30.2	-42.8	312.15	28	.12	447.45	101	608	.14	43
32000	323	14.7	.000	-32.9	-43.0	299.05	35	.12	433.54	97	604	.13	43
33000	326	15.7	.002	-35.4	-44.5	286.38	39	.10	419.57	94	601	.11	43
34000	327	17.1	.002	-37.8	-47.6	274.11	34	.07	405.63	91	598	.08	43
35000	324	15.9	.002	-40.2	-50.0	262.25	34	.06	392.12	88	595	.06	43
36000	317	14.6	.004	-42.4	-51.9	250.80	34	.05	378.61	85	592	.05	43
37000	310	14.9	.003	-44.8	-54.0	239.73	34	.04	365.67	82	589	.04	43
38000	311	16.4	.003	-46.6	-55.7	229.06	34	.03	352.19	79	587	.03	43
39000	315	17.7	.003	-49.0	-57.9	218.78	34	.02	340.08	76	584	.02	43
40000	323	18.6	.004	-51.6	-60.2	208.84	34	.02	328.37	73	580	.02	43
41000	330	18.9	.004	-54.0	-62.4	199.27	34	.01	316.82	71	577	.01	43
42000	337	19.3	.004	-56.5	-64.7	190.02	34	.01	305.61	68	574	.01	43
43000	339	20.2	.002	-58.8	-66.8	181.11	34	.01	294.32	66	571	.01	43
44000	340	21.7	.003	-61.2	99.9	172.53	999	99.99	283.64	63	567	.00999	
45000	341	22.8	.002	-63.1	99.9	164.27	999	99.99	272.39	61	565	.00999	
46000	342	22.6	.001	-65.0	99.9	156.34	999	99.99	261.64	58	562	.00999	
47000	342	21.2	.002	-67.5	99.9	148.71	999	99.99	251.90	56	559	.00999	
48000	338	20.3	.003	-69.7	99.9	141.38	999	99.99	242.04	54	556	.00999	
49000	339	20.1	.001	-72.1	99.9	134.33	999	99.99	232.83	52	553	.00999	
50000	350	19.3	.007	-72.8	99.9	127.58	999	99.99	221.84	49	552	.00999	
51000	5	17.9	.008	-73.8	99.9	121.15	999	99.99	211.68	47	550	.00999	

52000	14	15.2	.007	-76.2	99.9	115.00	999	99.99	203.41	45	547	.00999
53000	8	12.5	.005	-76.9	99.9	109.10	999	99.99	193.72	43	546	.00999
54000	2	12.5	.002	-76.7	99.9	103.50	999	99.99	183.57	41	546	.00999
55000	12	13.8	.004	-75.4	99.9	98.21	999	99.99	173.05	39	548	.00999
56000	33	14.0	.009	-75.0	99.9	93.22	999	99.99	163.87	37	549	.00999
57000	62	13.1	.011	-72.6	99.9	88.52	999	99.99	153.80	34	552	.00999
58000	83	12.3	.008	-72.2	99.9	84.08	999	99.99	145.79	32	553	.00999
59000	90	11.5	.003	-71.5	99.9	79.87	999	99.99	138.02	31	553	.00999
60000	95	11.4	.002	-68.4	99.9	75.92	999	99.99	129.17	29	558	.00999
61000	102	11.1	.003	-68.0	99.9	72.18	999	99.99	122.58	27	558	.00999
62000	104	10.1	.002	-67.5	99.9	68.65	999	99.99	116.27	26	559	.00999
63000	99	11.3	.003	-68.7	99.9	65.27	999	99.99	111.22	25	557	.00999
64000	90	13.6	.005	-68.5	99.9	62.06	999	99.99	105.64	24	558	.00999
65000	80	17.6	.008	-66.9	99.9	59.01	999	99.99	99.66	22	560	.00999
66000	72	21.0	.007	-65.1	99.9	56.15	999	99.99	94.00	21	562	.00999
67000	999	999.0	.999	-64.2	99.9	53.43	999	99.99	89.10	20	563	.00999

TERMINATION 67470 GEOPFT 20565 GEOPM 51.4 MBS
TROPOPAUSE 52636 FEET 111.22 MB -77.0 C 99.9 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
337	197	14	28.5	24.1	1000.0	78
1837	231	13	27.0	19.8	950.0	65
3399	241	11	22.4	18.4	900.0	78
5021	257	10	17.8	13.9	850.0	78
6720	283	10	15.9	4.0	800.0	45
8511	289	7	13.8	-4.2	750.0	28
10406	11	3	10.2	-1.3	700.0	45
12412	56	3	5.8	-6.2	650.0	42
14546	53	2	1.7	-8.6	600.0	46
16838	316	5	-1.1	-9.6	550.0	52
19316	291	11	-5.0	-22.2	500.0	24
22001	290	11	-10.8	-24.5	450.0	31
24945	301	6	-16.3	-30.3	400.0	28
28199	322	9	-23.3	-37.6	350.0	25
31832	323	15	-32.7	-43.0	300.0	35
35957	316	15	-42.6	-52.1	250.0	34
40784	330	19	-53.8	-62.2	200.0	34
43554	340	21	-60.5	99.9	175.0	999
46657	342	21	-67.1	99.9	150.0	999
50203	356	19	-72.9	99.9	125.0	999
54434	7	13	-76.6	99.9	100.0	999
58718	90	11	-71.6	99.9	80.0	999
61342	105	10	-67.3	99.9	70.0	999
64377	83	16	-68.0	99.9	60.0	999

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	180	6	28.5	25.1	1011.0	391	82
213	190	15	28.3	24.9	1004.2	388	82
608	212	13	28.9	22.3	990.8	365	68
1804	231	13	27.1	19.8	951.2	341	64
3535	241	11	22.0	18.3	895.9	326	80
4007	244	10	20.1	17.8	881.2	322	87
4583	250	10	18.3	17.7	863.5	319	96
5154	259	10	17.7	12.9	846.2	291	73
6864	284	10	15.7	3.1	796.2	248	43
8000	289	8	14.3	-2.1	764.4	230	32
8614	289	7	13.7	-4.5	747.6	222	28
9895	303	3	11.2	-5.2	713.7	214	31

10105	344	2	10.9	-4.8	708.2	213	33
11120	29	3	8.3	1.7	682.4	221	63
11340	41	3	7.7	1.1	676.9	218	63
11782	52	3	6.7	-.5	666.0	213	60
12376	56	3	5.9	-6.1	651.5	200	42
14049	55	2	2.4	-7.7	612.1	189	47
14590	53	2	1.7	-8.6	599.7	185	46
14773	53	1	1.5	-8.3	595.6	184	48
15141	360	0	.9	-13.3	587.4	177	34
15328	340	1	.9	-3.7	583.2	188	71
16250	324	4	-.5	-5.0	563.2	181	71
17459	310	7	-1.6	-13.5	537.9	165	40
18099	305	9	-3.2	-14.0	524.9	162	43
18728	298	10	-3.9	-20.4	512.4	154	26
24142	304	6	-14.2	-31.6	414.2	127	21
32416	324	15	-33.9	-43.0	293.7	96	39
34097	327	17	-38.0	-48.0	272.9	91	34
45333	342	23	-63.6	99.9	161.6	60	999
48943	338	20	-72.1	99.9	134.7	52	999
52636	12	13	-77.0	99.9	111.2	44	999
59627	93	11	-68.9	99.9	77.4	29	999
63378	97	12	-68.8	99.9	64.0	24	999
66577	71	22	-64.3	99.9	54.6	20	999
67786	999	999	-62.9	99.9	51.4	19	999

TERMINATION
076 076
NNNN

RS011842345
TEST NBR A4285 WS6A 1080
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
2345Z 02 JUL 96

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	180	5.0	.000	28.4	25.4	1011.00	84	23.28	1153.82	393	681	32.39	0
1000	224	12.0	.015	28.7	21.6	977.69	66	18.59	1117.20	357	681	25.89	6
2000	232	12.4	.003	26.6	19.6	944.81	65	16.49	1088.05	339	678	22.80	12
3000	238	11.8	.002	23.7	18.3	912.76	72	15.32	1062.04	328	674	20.99	16
4000	248	11.0	.003	20.6	17.9	881.47	84	15.09	1036.13	321	671	20.46	21
5000	261	10.5	.004	18.1	15.9	850.98	87	13.48	1009.81	306	668	18.11	25
6000	275	10.1	.004	16.6	11.5	821.29	72	10.16	981.33	280	666	13.59	29
7000	285	9.3	.003	15.6	4.5	792.48	48	6.37	952.21	251	664	8.49	31
8000	289	7.0	.004	14.3	-.5	764.52	36	4.45	923.77	233	662	5.91	33
9000	302	3.3	.007	13.1	-4.8	737.42	28	3.24	895.36	219	660	4.28	34
10000	1	2.0	.005	11.5	-3.8	711.14	35	3.56	868.21	215	658	4.67	35
11000	20	2.5	.001	9.1	1.0	685.65	57	5.06	843.26	219	656	6.58	36
12000	35	2.2	.001	7.3	-5.3	660.89	41	3.21	819.13	203	654	4.15	37
13000	51	2.5	.001	5.2	-7.2	636.84	40	2.77	795.26	195	651	3.56	38
14000	44	2.6	.001	3.1	-8.5	613.50	42	2.52	772.01	188	649	3.22	39
15000	21	2.2	.002	1.5	-8.3	590.85	48	2.57	748.04	183	647	3.26	40
16000	346	2.3	.002	.1	-5.2	568.94	68	3.30	723.42	182	645	4.16	41
17000	316	4.6	.005	-1.3	-8.0	547.74	61	2.69	700.38	173	643	3.38	42
18000	306	8.1	.006	-2.7	-14.1	527.22	41	1.67	678.03	162	642	2.08	42
19000	299	10.9	.005	-4.3	-19.9	507.35	28	1.02	656.70	153	639	1.26	43
20000	295	12.1	.002	-6.2	-21.4	488.10	29	.89	636.45	148	637	1.10	43
21000	294	11.5	.001	-8.4	-23.6	469.45	28	.75	617.37	142	634	.91	43
22000	999	999.0	.999	-10.4	-24.2	451.36	31	.71	597.93	138	632	.86	43

TERMINATION 22722 GEOPFT 6926 GEOPM 437.7 MBS
TROPOPAUSE 0 FEET .00 MB .0 C .0 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
337	207	11	28.5	24.6	1000.0	79
1838	231	12	27.0	19.8	950.0	65
3399	242	11	22.4	18.0	900.0	76
5024	261	10	18.0	15.7	850.0	87
6724	283	10	15.9	6.7	800.0	55
8516	291	5	13.9	-3.2	750.0	30
10413	16	2	10.6	-.2	700.0	47
12424	45	2	6.3	-6.7	650.0	39
14561	31	2	2.1	-8.5	600.0	45
16854	318	4	-1.2	-7.4	550.0	63
19333	297	12	-4.9	-20.7	500.0	27
22022	999	999	-10.5	-24.4	450.0	31

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	180	5	28.4	25.4	1011.0	393	84
216	202	11	28.3	25.3	1004.1	391	84
615	220	12	29.1	22.8	990.6	368	69
1862	232	12	27.0	19.8	949.3	341	65
3719	245	11	21.5	17.9	890.2	323	80
4359	251	11	19.5	17.8	870.4	320	90
6241	278	10	16.2	11.0	814.3	277	71
7481	289	8	15.0	.6	778.9	239	37

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  8717 292    5  13.8   -4.3   745.0 222   28
  9798 354    2  11.9   -5.5   716.4 214   29
 10443  16    2  10.6    -.2   699.8 219   47
 11068  20    3   8.9    1.2   683.9 219   58
 12204  41    2   6.8   -6.5   655.9 200   38
 14125  41    3   2.9   -8.6   610.6 187   42
 16059 344    2    .0   -4.9   567.7 182   69
 18144 305    9  -2.9  -15.1   524.3 160   38
 19526 296   12  -5.1  -21.1   497.2 150   27
 22147 999  999 -10.6  -24.6   448.7 137   31
 22779 999  999 -11.4  -28.9   437.7 133   22
TERMINATION
154 154
NNNN
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Meteorological Tower Data -- 3 July 1996 0030Z

DAY	TIME	LAT	LON	Z	DIR	SPD	T	TD	TIDN
96185	3000	28.4338	80.5734	6			83		1
96185	3000	28.4338	80.5734	12	184	2.9			1
96185	3000	28.4338	80.5734	54	177	7.0	83		1
96185	3000	28.4443	80.5621	6			83	79	2
96185	3000	28.4443	80.5621	12	166	2.9			2
96185	3000	28.4443	80.5621	54	167	8.0	83	79	2
96185	3000	28.4443	80.5621	90	174	9.9			2
96185	3000	28.4443	80.5621	162	184	9.9			2
96185	3000	28.4443	80.5621	204	192	9.9	85	77	2
96185	3000	28.4443	80.5621	6			83	81	2
96185	3000	28.4443	80.5621	12	171	2.9			2
96185	3000	28.4443	80.5621	54	174	7.0	84	79	2
96185	3000	28.4443	80.5621	90	178	8.9			2
96185	3000	28.4443	80.5621	162	190	9.9			2
96185	3000	28.4443	80.5621	204	193	9.9	85	77	2
96185	3000	28.4598	80.5267	6			83		3
96185	3000	28.4598	80.5267	12	182	6.0			3
96185	3000	28.4598	80.5267	54	177	8.9	83		3
96185	3000	28.4466	80.5652	6					17
96185	3000	28.7435	80.7005	6					19
96185	3000	28.7435	80.7005	54	0	0.0			19
96185	3000	28.7975	80.7378	6					22
96185	3000	28.7975	80.7378	54					22
96185	3000	28.4721	80.5393	6					36
96185	3000	28.4721	80.5393	90	181	7.0			36
96185	3000	28.5622	80.5785	6					40
96185	3000	28.5622	80.5785	54	175	7.0			40
96185	3000	28.5836	80.5842	6					41
96185	3000	28.5836	80.5842	54	157	7.0			41
96185	3000	28.5130	80.5613	6			82	79	61
96185	3000	28.5130	80.5613	12	164	1.0			61
96185	3000	28.5130	80.5613	54	177	4.1	82	77	61
96185	3000	28.5130	80.5613	162	180	8.9			61
96185	3000	28.5130	80.5613	204	184	9.9	83	76	61
96185	3000	28.5130	80.5613	6			82	78	62
96185	3000	28.5130	80.5613	12	171	1.0			62
96185	3000	28.5130	80.5613	54	178	4.1	82	76	62
96185	3000	28.5130	80.5613	162	183	8.0			62
96185	3000	28.5130	80.5613	204	187	9.9	83	77	62
96185	3000	28.5358	80.5747	6			82		108
96185	3000	28.5358	80.5747	12	166	1.9			108
96185	3000	28.5358	80.5747	54	167	6.0	83		108
96185	3000	28.6141	80.6203	6			82		112
96185	3000	28.6141	80.6203	12	177	1.9			112
96185	3000	28.6141	80.6203	54	182	5.1	84		112
96185	3000	28.4048	80.6519	6			88	72	300
96185	3000	28.4048	80.6519	54	238	8.0			300
96185	3000	28.4600	80.5711	6			82		303
96185	3000	28.4600	80.5711	12	171	1.0			303
96185	3000	28.4600	80.5711	54	174	4.1	82		303
96185	3000	28.6027	80.6414	6			85		311
96185	3000	28.6027	80.6414	12	218	4.1			311
96185	3000	28.6027	80.6414	54	218	7.0	87		311
96185	3000	28.6105	80.6069	6					393
96185	3000	28.6105	80.6069	60	181	7.0	85	78	393
96185	3000	28.6057	80.6016	6			85	77	394
96185	3000	28.6057	80.6016	60	189	8.0	86	79	394
96185	3000	28.6294	80.6235	6					397

96185	3000	28.6294	80.6235	60	182	5.1	85	78	397
96185	3000	28.6248	80.6182	6			85	79	398
96185	3000	28.6248	80.6182	60	176	5.1	85	78	398
96185	3000	28.4586	80.5923	6			85		403
96185	3000	28.4586	80.5923	12	214	2.9			403
96185	3000	28.4586	80.5923	54	226	6.0	87		403
96185	3000	28.6062	80.6739	6			85		412
96185	3000	28.6062	80.6739	12	199	1.0			412
96185	3000	28.6062	80.6739	54	208	2.9	86		412
96185	3000	28.6586	80.6998	6			83		415
96185	3000	28.6586	80.6998	12	219	1.0			415
96185	3000	28.6586	80.6998	54	221	4.1	85		415
96185	3000	28.7055	80.7265	6					418
96185	3000	28.7055	80.7265	54					418
96185	3000	28.7755	80.8043	6					421
96185	3000	28.7755	80.8043	54					421
96185	3000	28.5158	80.6400	6			85		506
96185	3000	28.5158	80.6400	12	217	2.9			506
96185	3000	28.5158	80.6400	54	218	5.1	87		506
96185	3000	28.5623	80.6694	6					509
96185	3000	28.5623	80.6694	12	224	2.9			509
96185	3000	28.5623	80.6694	54	218	5.1	83		509
96185	3000	28.5986	80.6817	6					511
96185	3000	28.5986	80.6817	30	218	6.0			511
96185	3000	28.6160	80.6930	6			87	73	512
96185	3000	28.6160	80.6930	30	170	6.0			512
96185	3000	28.6307	80.7027	6					513
96185	3000	28.6307	80.7027	30	209	5.1			513
96185	3000	28.6431	80.7482	6			85		714
96185	3000	28.6431	80.7482	12	230	1.9			714
96185	3000	28.6431	80.7482	54	225	6.0	86		714
96185	3000	28.4632	80.6702	6			84		803
96185	3000	28.4632	80.6702	12	211	1.9			803
96185	3000	28.4632	80.6702	54	226	4.1	86		803
96185	3000	28.5184	80.6962	6			82		805
96185	3000	28.5184	80.6962	12	215	0.0			805
96185	3000	28.5184	80.6962	54	212	4.1	85		805
96185	3000	28.7464	80.8707	6					819
96185	3000	28.7464	80.8707	54					819
96185	3000	28.4079	80.7604	6					1000
96185	3000	28.4079	80.7604	54					1000
96185	3000	28.5272	80.7742	6			87	73	1007
96185	3000	28.5272	80.7742	54	211	7.0			1007
96185	3000	28.6056	80.8248	6					1012
96185	3000	28.6056	80.8248	54					1012
96185	3000	28.5697	80.5864	6			85	80	1101
96185	3000	28.5697	80.5864	12	154	1.9			1101
96185	3000	28.5697	80.5864	54	169	6.0	85	80	1101
96185	3000	28.5697	80.5864	162	181	8.0			1101
96185	3000	28.5697	80.5864	204	179	8.9	85	78	1101
96185	3000	28.5697	80.5864	6			84	80	1102
96185	3000	28.5697	80.5864	12	157	1.9			1102
96185	3000	28.5697	80.5864	54	176	6.0	84	79	1102
96185	3000	28.5697	80.5864	162	179	8.0			1102
96185	3000	28.5697	80.5864	204	188	8.9	85	77	1102
96185	3000	28.4843	80.7856	6			85	76	1204
96185	3000	28.4843	80.7856	54	216	2.9			1204
96185	3000	28.6445	80.9034	6					1215
96185	3000	28.4114	80.9284	6					1500
96185	3000	28.4114	80.9284	54					1500
96185	3000	28.4475	80.8538	6					1502

96185	3000	28.4960	80.8843	6					1605
96185	3000	28.4960	80.8843	54					1605
96185	3000	28.5583	80.9132	6					1609
96185	3000	28.6173	80.9581	6					1612
96185	3000	28.6173	80.9581	54					1612
96185	3000	28.6762	80.9987	6					1617
96185	3000	28.6762	80.9987	54					1617
96185	3000	28.5231	81.0100	6					2008
96185	3000	28.5231	81.0100	54					2008
96185	3000	28.6489	81.0693	6					2016
96185	3000	28.6489	81.0693	54					2016
96185	3000	28.4417	81.0291	6					2202
96185	3000	28.4417	81.0291	54					2202
96185	3000	28.6256	80.6571	6			85	73	3131
96185	3000	28.6256	80.6571	12	211	0.0			3131
96185	3000	28.6256	80.6571	54	221	4.1	86	72	3131
96185	3000	28.6256	80.6571	162	222	8.0			3131
96185	3000	28.6256	80.6571	204	225	7.0	87	71	3131
96185	3000	28.6256	80.6571	295	233	8.9			3131
96185	3000	28.6256	80.6571	394	226	8.9			3131
96185	3000	28.6256	80.6571	492	231	8.9	87	70	3131
96185	3000	28.6256	80.6571	6			85	74	3132
96185	3000	28.6256	80.6571	12	205	1.0			3132
96185	3000	28.6256	80.6571	54	220	4.1	86	73	3132
96185	3000	28.6256	80.6571	162	221	8.9			3132
96185	3000	28.6256	80.6571	204	229	9.9	87	71	3132
96185	3000	28.6256	80.6571	295	229	12.1			3132
96185	3000	28.6256	80.6571	394	234	13.0			3132
96185	3000	28.6256	80.6571	492	235	14.0	87	69	3132
96185	3000	28.3932	80.8211	6					9001
96185	3000	28.3932	80.8211	54					9001
96185	3000	28.3382	80.7321	6					9404
96185	3000	28.3382	80.7321	54					9404

Meteorological Tower Data -- 3 July 1996 0040Z

DAY	TIME	LAT	LON	Z	DIR	SPD	T	TD	TIDN
96185	4000	28.4338	80.5734	6			83		1
96185	4000	28.4338	80.5734	12	182	2.9			1
96185	4000	28.4338	80.5734	54	182	7.0	84		1
96185	4000	28.4443	80.5621	6			83	79	2
96185	4000	28.4443	80.5621	12	179	1.9			2
96185	4000	28.4443	80.5621	54	174	7.0	83	78	2
96185	4000	28.4443	80.5621	90	182	8.9			2
96185	4000	28.4443	80.5621	162	193	8.9			2
96185	4000	28.4443	80.5621	204	203	8.9	86	76	2
96185	4000	28.4443	80.5621	6			83	81	2
96185	4000	28.4443	80.5621	12	183	1.9			2
96185	4000	28.4443	80.5621	54	182	7.0	84	79	2
96185	4000	28.4443	80.5621	90	186	8.9			2
96185	4000	28.4443	80.5621	162	198	8.9			2
96185	4000	28.4443	80.5621	204	204	8.9	86	76	2
96185	4000	28.4598	80.5267	6			82		3
96185	4000	28.4598	80.5267	12	182	6.0			3
96185	4000	28.4598	80.5267	54	179	8.9	83		3
96185	4000	28.4466	80.5652	6					17
96185	4000	28.7435	80.7005	6			75		19
96185	4000	28.7435	80.7005	54	0	0.0			19
96185	4000	28.7975	80.7378	6			87	75	22
96185	4000	28.7975	80.7378	54	258	7.0			22
96185	4000	28.4721	80.5393	6					36
96185	4000	28.4721	80.5393	90	190	7.0			36
96185	4000	28.5622	80.5785	6					40
96185	4000	28.5622	80.5785	54	176	6.0			40
96185	4000	28.5836	80.5842	6					41
96185	4000	28.5836	80.5842	54	164	6.0			41
96185	4000	28.5130	80.5613	6			82	79	61
96185	4000	28.5130	80.5613	12	176	1.0			61
96185	4000	28.5130	80.5613	54	177	4.1	82	77	61
96185	4000	28.5130	80.5613	162	183	8.9			61
96185	4000	28.5130	80.5613	204	191	9.9	84	75	61
96185	4000	28.5130	80.5613	6			81	78	62
96185	4000	28.5130	80.5613	12	180	0.0			62
96185	4000	28.5130	80.5613	54	179	4.1	82	76	62
96185	4000	28.5130	80.5613	162	186	8.9			62
96185	4000	28.5130	80.5613	204	194	9.9	84	76	62
96185	4000	28.5358	80.5747	6			81		108
96185	4000	28.5358	80.5747	12	163	1.9			108
96185	4000	28.5358	80.5747	54	166	5.1	83		108
96185	4000	28.6141	80.6203	6			82		112
96185	4000	28.6141	80.6203	12	198	2.9			112
96185	4000	28.6141	80.6203	54	201	4.1	85		112
96185	4000	28.4048	80.6519	6					300
96185	4000	28.4048	80.6519	54					300
96185	4000	28.4600	80.5711	6			81		303
96185	4000	28.4600	80.5711	12	166	0.0			303
96185	4000	28.4600	80.5711	54	172	4.1	82		303
96185	4000	28.6027	80.6414	6			85		311
96185	4000	28.6027	80.6414	12	218	4.1			311
96185	4000	28.6027	80.6414	54	215	7.0	87		311
96185	4000	28.6105	80.6069	6					393
96185	4000	28.6105	80.6069	60	192	5.1	85	77	393
96185	4000	28.6057	80.6016	6			85	76	394
96185	4000	28.6057	80.6016	60	198	7.0	86	78	394
96185	4000	28.6294	80.6235	6					397

96185	4000	28.6294	80.6235	60	201	6.0	85	74	397
96185	4000	28.6248	80.6182	6			85	78	398
96185	4000	28.6248	80.6182	60	187	5.1	85	78	398
96185	4000	28.4586	80.5923	6			87		403
96185	4000	28.4586	80.5923	12	219	5.1			403
96185	4000	28.4586	80.5923	54	227	7.0	87		403
96185	4000	28.6062	80.6739	6			84		412
96185	4000	28.6062	80.6739	12	190	1.9			412
96185	4000	28.6062	80.6739	54	203	2.9	85		412
96185	4000	28.6586	80.6998	6			82		415
96185	4000	28.6586	80.6998	12	231	0.0			415
96185	4000	28.6586	80.6998	54	217	2.9	84		415
96185	4000	28.7055	80.7265	6					418
96185	4000	28.7055	80.7265	54					418
96185	4000	28.7755	80.8043	6					421
96185	4000	28.7755	80.8043	54					421
96185	4000	28.5158	80.6400	6			85		506
96185	4000	28.5158	80.6400	12	217	4.1			506
96185	4000	28.5158	80.6400	54	223	6.0	86		506
96185	4000	28.5623	80.6694	6					509
96185	4000	28.5623	80.6694	12	221	1.9			509
96185	4000	28.5623	80.6694	54	217	5.1	83		509
96185	4000	28.5986	80.6817	6					511
96185	4000	28.5986	80.6817	30	212	5.1			511
96185	4000	28.6160	80.6930	6			87	73	512
96185	4000	28.6160	80.6930	30	170	6.0			512
96185	4000	28.6307	80.7027	6					513
96185	4000	28.6307	80.7027	30	211	6.0			513
96185	4000	28.6431	80.7482	6			84		714
96185	4000	28.6431	80.7482	12	224	1.9			714
96185	4000	28.6431	80.7482	54	221	6.0	86		714
96185	4000	28.4632	80.6702	6			84		803
96185	4000	28.4632	80.6702	12	211	1.9			803
96185	4000	28.4632	80.6702	54	226	4.1	85		803
96185	4000	28.5184	80.6962	6			80		805
96185	4000	28.5184	80.6962	12	215	0.0			805
96185	4000	28.5184	80.6962	54	210	4.1	84		805
96185	4000	28.7464	80.8707	6					819
96185	4000	28.7464	80.8707	54					819
96185	4000	28.4079	80.7604	6					1000
96185	4000	28.4079	80.7604	54					1000
96185	4000	28.5272	80.7742	6			86	74	1007
96185	4000	28.5272	80.7742	54	210	7.0			1007
96185	4000	28.6056	80.8248	6					1012
96185	4000	28.6056	80.8248	54					1012
96185	4000	28.5697	80.5864	6			84	80	1101
96185	4000	28.5697	80.5864	12	166	1.9			1101
96185	4000	28.5697	80.5864	54	179	6.0	85	79	1101
96185	4000	28.5697	80.5864	162	188	8.0			1101
96185	4000	28.5697	80.5864	204	187	8.0	85	77	1101
96185	4000	28.5697	80.5864	6			84	80	1102
96185	4000	28.5697	80.5864	12	167	1.9			1102
96185	4000	28.5697	80.5864	54	187	6.0	84	78	1102
96185	4000	28.5697	80.5864	162	186	8.0			1102
96185	4000	28.5697	80.5864	204	196	8.0	85	77	1102
96185	4000	28.4843	80.7856	6					1204
96185	4000	28.4843	80.7856	54					1204
96185	4000	28.6445	80.9034	6					1215
96185	4000	28.4114	80.9284	6					1500
96185	4000	28.4114	80.9284	54					1500
96185	4000	28.4475	80.8538	6					1502

96185	4000	28.4960	80.8843	6					1605
96185	4000	28.4960	80.8843	54					1605
96185	4000	28.5583	80.9132	6					1609
96185	4000	28.6173	80.9581	6					1612
96185	4000	28.6173	80.9581	54					1612
96185	4000	28.6762	80.9987	6					1617
96185	4000	28.6762	80.9987	54					1617
96185	4000	28.5231	81.0100	6					2008
96185	4000	28.5231	81.0100	54					2008
96185	4000	28.6489	81.0693	6					2016
96185	4000	28.6489	81.0693	54					2016
96185	4000	28.4417	81.0291	6					2202
96185	4000	28.4417	81.0291	54					2202
96185	4000	28.6256	80.6571	6			84	74	3131
96185	4000	28.6256	80.6571	12	205	0.0			3131
96185	4000	28.6256	80.6571	54	219	4.1	86	73	3131
96185	4000	28.6256	80.6571	162	220	8.0			3131
96185	4000	28.6256	80.6571	204	222	8.0	87	71	3131
96185	4000	28.6256	80.6571	295	231	8.0			3131
96185	4000	28.6256	80.6571	394	224	8.9			3131
96185	4000	28.6256	80.6571	492	229	8.0	86	70	3131
96185	4000	28.6256	80.6571	6			84	75	3132
96185	4000	28.6256	80.6571	12	199	0.0			3132
96185	4000	28.6256	80.6571	54	215	4.1	85	73	3132
96185	4000	28.6256	80.6571	162	219	8.0			3132
96185	4000	28.6256	80.6571	204	227	8.9	87	72	3132
96185	4000	28.6256	80.6571	295	227	11.1			3132
96185	4000	28.6256	80.6571	394	232	12.1			3132
96185	4000	28.6256	80.6571	492	233	13.0	86	69	3132
96185	4000	28.3932	80.8211	6					9001
96185	4000	28.3932	80.8211	54					9001
96185	4000	28.3382	80.7321	6					9404
96185	4000	28.3382	80.7321	54					9404

Meteorological Tower Data -- 3 July 1996 0050Z

DAY	TIME	LAT	LON	Z	DIR	SPD	T	TD	TIDN
96185	5000	28.4338	80.5734	6			83		1
96185	5000	28.4338	80.5734	12	203	1.9			1
96185	5000	28.4338	80.5734	54	200	5.1	84		1
96185	5000	28.4443	80.5621	6			83	79	2
96185	5000	28.4443	80.5621	12	186	1.9			2
96185	5000	28.4443	80.5621	54	185	6.0	83	78	2
96185	5000	28.4443	80.5621	90	193	8.0			2
96185	5000	28.4443	80.5621	162	202	8.0			2
96185	5000	28.4443	80.5621	204	206	8.0	86	77	2
96185	5000	28.4443	80.5621	6			83	80	2
96185	5000	28.4443	80.5621	12	192	1.9			2
96185	5000	28.4443	80.5621	54	192	6.0	84	79	2
96185	5000	28.4443	80.5621	90	197	8.0			2
96185	5000	28.4443	80.5621	162	207	8.0			2
96185	5000	28.4443	80.5621	204	207	8.0	86	76	2
96185	5000	28.4598	80.5267	6			82		3
96185	5000	28.4598	80.5267	12	188	5.1			3
96185	5000	28.4598	80.5267	54	184	8.0	83		3
96185	5000	28.4466	80.5652	6					17
96185	5000	28.7435	80.7005	6			94		19
96185	5000	28.7435	80.7005	54	0	0.0			19
96185	5000	28.7975	80.7378	6					22
96185	5000	28.7975	80.7378	54					22
96185	5000	28.4721	80.5393	6					36
96185	5000	28.4721	80.5393	90	192	7.0			36
96185	5000	28.5622	80.5785	6					40
96185	5000	28.5622	80.5785	54	176	6.0			40
96185	5000	28.5836	80.5842	6					41
96185	5000	28.5836	80.5842	54	165	5.1			41
96185	5000	28.5130	80.5613	6			81	79	61
96185	5000	28.5130	80.5613	12	163	0.0			61
96185	5000	28.5130	80.5613	54	178	4.1	82	77	61
96185	5000	28.5130	80.5613	162	195	8.9			61
96185	5000	28.5130	80.5613	204	204	8.0	85	73	61
96185	5000	28.5130	80.5613	6			81	78	62
96185	5000	28.5130	80.5613	12	174	0.0			62
96185	5000	28.5130	80.5613	54	179	4.1	82	76	62
96185	5000	28.5130	80.5613	162	198	8.9			62
96185	5000	28.5130	80.5613	204	208	8.9	85	74	62
96185	5000	28.5358	80.5747	6			81		108
96185	5000	28.5358	80.5747	12	150	1.9			108
96185	5000	28.5358	80.5747	54	171	5.1	83		108
96185	5000	28.6141	80.6203	6			83		112
96185	5000	28.6141	80.6203	12	215	4.1			112
96185	5000	28.6141	80.6203	54	210	6.0	85		112
96185	5000	28.4048	80.6519	6					300
96185	5000	28.4048	80.6519	54					300
96185	5000	28.4600	80.5711	6			80		303
96185	5000	28.4600	80.5711	12	172	0.0			303
96185	5000	28.4600	80.5711	54	179	4.1	82		303
96185	5000	28.6027	80.6414	6			85		311
96185	5000	28.6027	80.6414	12	221	4.1			311
96185	5000	28.6027	80.6414	54	217	8.0	86		311
96185	5000	28.6105	80.6069	6					393
96185	5000	28.6105	80.6069	60	201	5.1	85	76	393
96185	5000	28.6057	80.6016	6			85	76	394
96185	5000	28.6057	80.6016	60	208	6.0	85	78	394
96185	5000	28.6294	80.6235	6					397

96185	5000	28.6294	80.6235	60	207	7.0	85	74	397
96185	5000	28.6248	80.6182	6			85	75	398
96185	5000	28.6248	80.6182	60	203	6.0	85	76	398
96185	5000	28.4586	80.5923	6			87		403
96185	5000	28.4586	80.5923	12	233	6.0			403
96185	5000	28.4586	80.5923	54	233	7.0	87		403
96185	5000	28.6062	80.6739	6			83		412
96185	5000	28.6062	80.6739	12	180	1.0			412
96185	5000	28.6062	80.6739	54	202	2.9	85		412
96185	5000	28.6586	80.6998	6			82		415
96185	5000	28.6586	80.6998	12	219	0.0			415
96185	5000	28.6586	80.6998	54	219	4.1	83		415
96185	5000	28.7055	80.7265	6					418
96185	5000	28.7055	80.7265	54					418
96185	5000	28.7755	80.8043	6					421
96185	5000	28.7755	80.8043	54					421
96185	5000	28.5158	80.6400	6			85		506
96185	5000	28.5158	80.6400	12	225	4.1			506
96185	5000	28.5158	80.6400	54	226	5.1	86		506
96185	5000	28.5623	80.6694	6					509
96185	5000	28.5623	80.6694	12	216	1.9			509
96185	5000	28.5623	80.6694	54	218	5.1	83		509
96185	5000	28.5986	80.6817	6					511
96185	5000	28.5986	80.6817	30	206	4.1			511
96185	5000	28.6160	80.6930	6			87	73	512
96185	5000	28.6160	80.6930	30	170	5.1			512
96185	5000	28.6307	80.7027	6					513
96185	5000	28.6307	80.7027	30	210	6.0			513
96185	5000	28.6431	80.7482	6			84		714
96185	5000	28.6431	80.7482	12	219	1.9			714
96185	5000	28.6431	80.7482	54	215	5.1	85		714
96185	5000	28.4632	80.6702	6			83		803
96185	5000	28.4632	80.6702	12	210	1.9			803
96185	5000	28.4632	80.6702	54	226	4.1	85		803
96185	5000	28.5184	80.6962	6			80		805
96185	5000	28.5184	80.6962	12	198	0.0			805
96185	5000	28.5184	80.6962	54	216	4.1	84		805
96185	5000	28.7464	80.8707	6					819
96185	5000	28.7464	80.8707	54					819
96185	5000	28.4079	80.7604	6					1000
96185	5000	28.4079	80.7604	54					1000
96185	5000	28.5272	80.7742	6			86	74	1007
96185	5000	28.5272	80.7742	54	210	7.0			1007
96185	5000	28.6056	80.8248	6					1012
96185	5000	28.6056	80.8248	54					1012
96185	5000	28.5697	80.5864	6			84	79	1101
96185	5000	28.5697	80.5864	12	163	1.9			1101
96185	5000	28.5697	80.5864	54	180	6.0	85	79	1101
96185	5000	28.5697	80.5864	162	207	7.0			1101
96185	5000	28.5697	80.5864	204	208	8.0	85	75	1101
96185	5000	28.5697	80.5864	6			84	79	1102
96185	5000	28.5697	80.5864	12	169	1.9			1102
96185	5000	28.5697	80.5864	54	188	6.0	85	78	1102
96185	5000	28.5697	80.5864	162	206	7.0			1102
96185	5000	28.5697	80.5864	204	216	8.0	86	75	1102
96185	5000	28.4843	80.7856	6			84	75	1204
96185	5000	28.4843	80.7856	54	212	4.1			1204
96185	5000	28.6445	80.9034	6					1215
96185	5000	28.4114	80.9284	6					1500
96185	5000	28.4114	80.9284	54					1500
96185	5000	28.4475	80.8538	6					1502

96185	5000	28.4960	80.8843	6					1605
96185	5000	28.4960	80.8843	54					1605
96185	5000	28.5583	80.9132	6					1609
96185	5000	28.6173	80.9581	6					1612
96185	5000	28.6173	80.9581	54					1612
96185	5000	28.6762	80.9987	6					1617
96185	5000	28.6762	80.9987	54					1617
96185	5000	28.5231	81.0100	6					2008
96185	5000	28.5231	81.0100	54					2008
96185	5000	28.6489	81.0693	6					2016
96185	5000	28.6489	81.0693	54					2016
96185	5000	28.4417	81.0291	6					2202
96185	5000	28.4417	81.0291	54					2202
96185	5000	28.6256	80.6571	6			84	74	3131
96185	5000	28.6256	80.6571	12	199	0.0			3131
96185	5000	28.6256	80.6571	54	216	4.1	85	73	3131
96185	5000	28.6256	80.6571	162	220	8.9			3131
96185	5000	28.6256	80.6571	204	223	8.0	87	71	3131
96185	5000	28.6256	80.6571	295	231	8.0			3131
96185	5000	28.6256	80.6571	394	223	8.9			3131
96185	5000	28.6256	80.6571	492	229	8.0	86	71	3131
96185	5000	28.6256	80.6571	6			84	75	3132
96185	5000	28.6256	80.6571	12	199	1.0			3132
96185	5000	28.6256	80.6571	54	212	4.1	85	73	3132
96185	5000	28.6256	80.6571	162	219	8.9			3132
96185	5000	28.6256	80.6571	204	227	8.9	87	72	3132
96185	5000	28.6256	80.6571	295	227	11.1			3132
96185	5000	28.6256	80.6571	394	231	13.0			3132
96185	5000	28.6256	80.6571	492	233	14.0	86	68	3132
96185	5000	28.3932	80.8211	6					9001
96185	5000	28.3932	80.8211	54					9001
96185	5000	28.3382	80.7321	6					9404
96185	5000	28.3382	80.7321	54					9404